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(English Edition)

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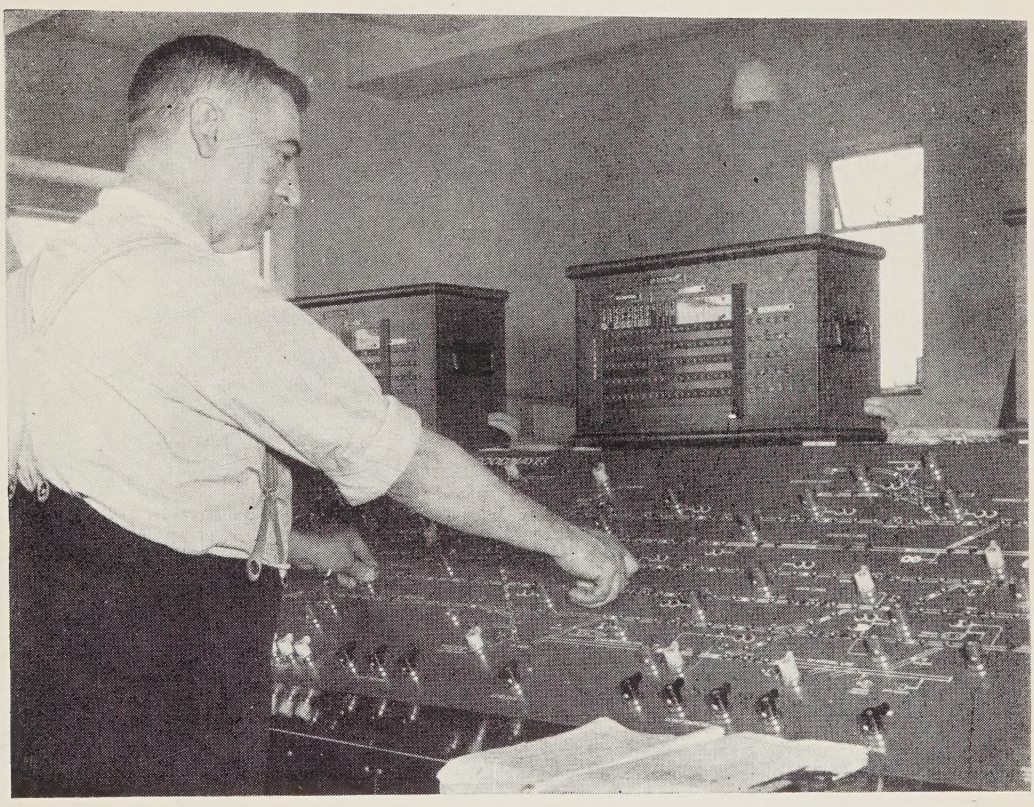

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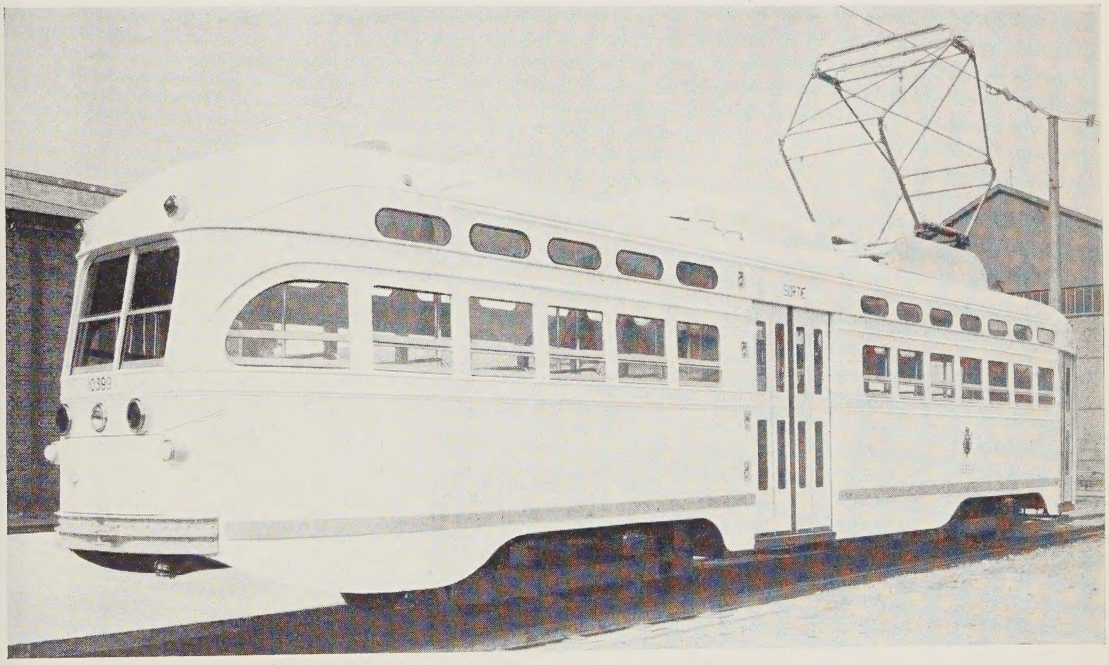

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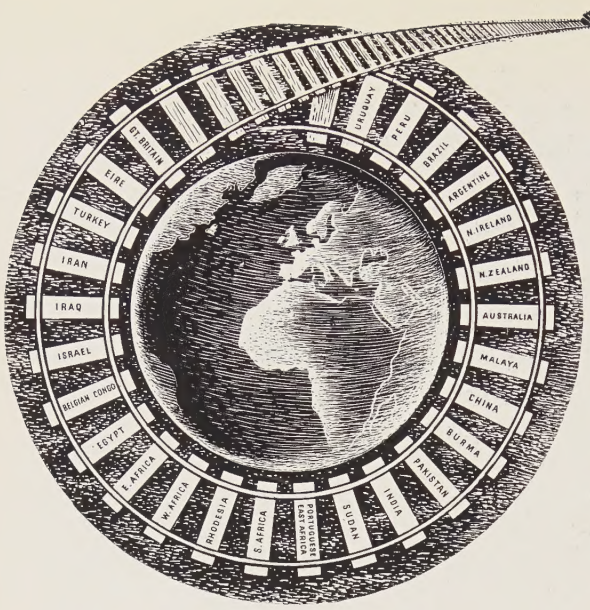

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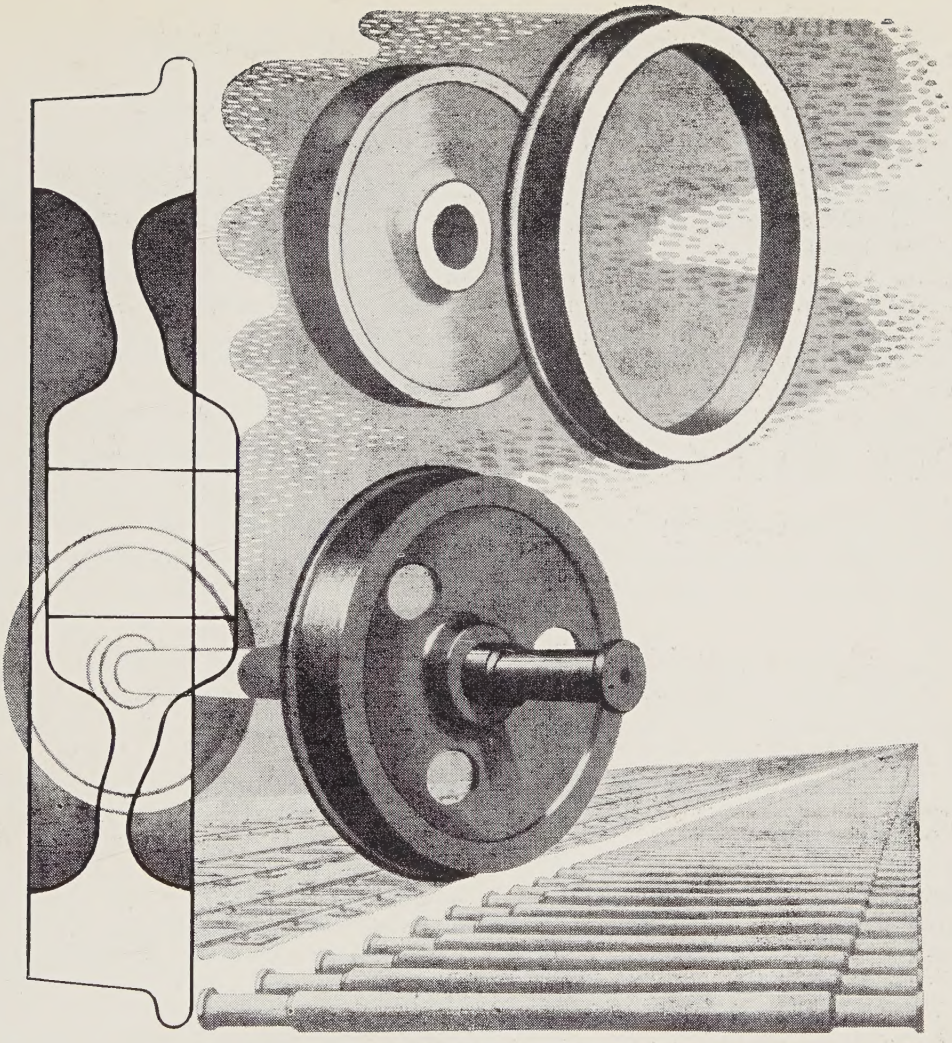

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CONTENTS OF THE NUMBER FOR FEBRUARY, 1951.

CONTENTS.	Page.
I. Research into a method of **calculating the stopping distance in the case of goods trains retarded by continuous compressed air brakes,** with progressive charging of the brake cylinders *(Continuation and end)*, by Edgar HENNIG	53
II. **Lighting coaches by fluorescent tubes** using 72 Volts D. C., by M. MICHOTTE and E. UYTBORCK.	73
III. **Testing new locomotives** of the London, Midland & Scottish Railway (Great Britain) on the line	82
IV. **New rolling stock** of the Italian State Railways	85
V. The experimental **coal-burning gas turbine,** by John I. YELLOTT	90
VI. British Railways **first gas-turbine locomotive**	96

CONTENTS *(continued)*. Page.

VII. NEW BOOKS AND PUBLICATIONS :

Bogengestaltung und Bogenabsteckung *(The constitution of curves and their layout on site)*, by G. SCHRAMM 110

Le Ferrovie italiane dello State *(La reconstruzione alla fine del 1949) (The Italian State Railways. — Their reconstruction at the end of 1949)* 111

Calculo, planos de construcción y ensayos de una linea catenaria para electrificación de ferrocarriles *(Calculation, constructional plans and tests for an overhead line for electric railways)* 112

VIII. MONTHLY BIBLIOGRAPHY OF RAILWAYS 9

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An edition in French is also published.

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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[625 .251]

Research into a method of calculating the stopping distance in the case of goods trains retarded by continuous compressed air brakes, with progressive charging of the brake cylinders,

*(Continuation and end)**

by Edgar HENNIG,

Ingénieur Civil des Mines, Ingénieur principal honoraire S. N. C. B.

CHAPTER III.

Numerical application (fig. 7).

Let us take as in the numerical example dealt with in the first part of this study (*Bulletin* of April 1948), a goods train again formed of a rake of wagons (of which 30 % are empties) weighing 1200 tonnes hauled by a single 8 1 type S. N. C. B. locomotive weighing 112 tonnes tender included.

The length of the rake is taken as 500 m and that of the locomotive as 18 m (tender included).

The train so formed is supposed to be located in the same set of conditions as those of the example given in the beginning of the Second Part (fig. 1) and L_0 is taken as equal to 550 m, $i_1 = 5$ mm per m and $i_2 = 2$ mm per m.

Finally, we can suppose as before that :

— the speed v_A when the braking starts is 54 km/h (or 15 m per second);

— the coefficient of majoration $\eta = 1.08$;

— the law of variation of the coefficient (f) of the friction of the brake blocks on the tyres can be written at speeds under 54 km/h according to Doyen :

$$f = a - bv$$

with $a = 0.27$ and $b = 0.0072$.

The numerical values of the general constants are then the following :

$$\left.\begin{array}{l} P_1 = 112 \text{ tonnes} \\ l_1 = 18 \text{ metres} \end{array}\right\} \quad p_1 = \frac{P_1}{l_1} = \frac{112}{18} = 6.222 \text{ tonnes.}$$

$$\left.\begin{array}{l} P' = 1200 \text{ tonnes} \\ L' = 500 \text{ metres} \end{array}\right\} \quad p' = \frac{P'}{L'} = \frac{1200}{500} = 2.4 \text{ tonnes.}$$

(*) See the *Congress Bulletins* for March (p. 139) and April (p. 201) 1948; and February (p. 77) 1950.

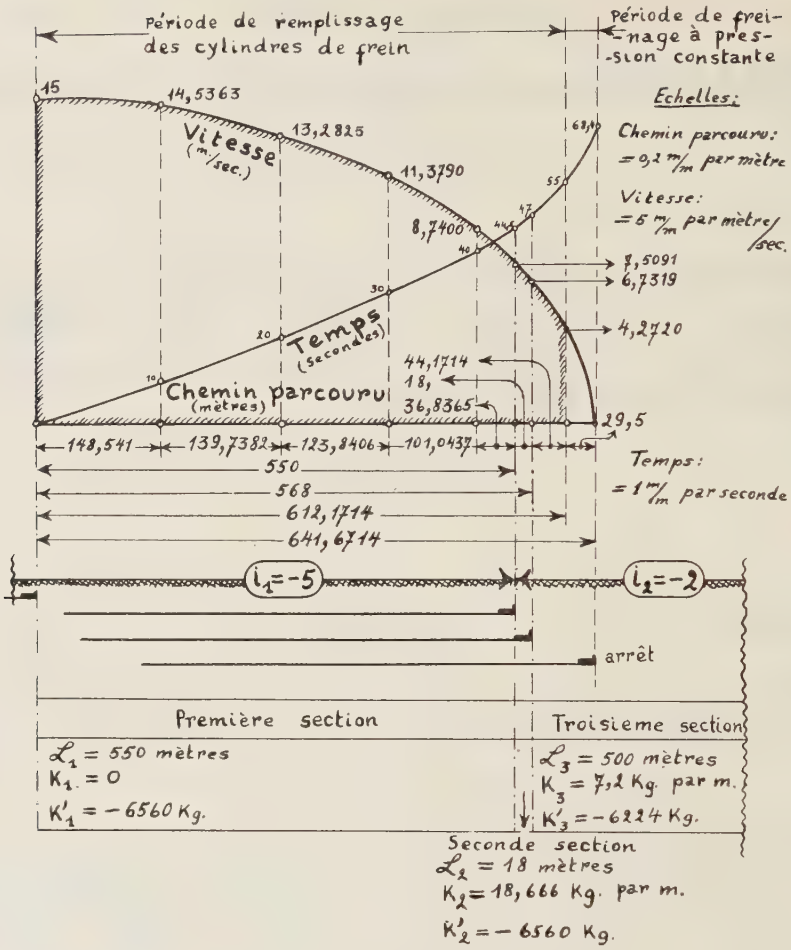

Fig. 7. — Numerical example.

Explanation of French terms :

Période de remplissage des cylindres de frein = Period of refilling the brake cylinders. — Période de freinage à pression constante = Period of braking at constant pressure. — Vitesse = Speed. — Chemin parcouru = Distance travelled. — Temps (secondes) = Time (seconds). — Première section = 1st section. — Seconde section = 2nd section. — Troisième section = 3rd section.

$$P = P_1 + P' = 112 + 1200 = 1312 \text{ tonnes.}$$

$$L = l_1 + L' = 18 + 500 = 518 \text{ metres.}$$

$$v_A = 15 \text{ metres per second.}$$

$$M = \frac{1000 \times P \times \eta}{g} = \frac{1000 \times 1312 \times 1.08}{9.81} = 144436$$

$$\frac{1}{M} = \frac{g}{1000 \times P \times \eta} = \frac{9.81}{1000 \times 1312 \times 1.08} = \frac{7}{10^6}$$

$$i_1 = -5$$

$$i_2 = -2$$

In addition referring to the appendix to the first part (*Bulletin* of April 1948), we can again use the values :

r_A = specific resistance of the rake (with 30 % empties) at speed V_A (or 54 km/h or 15 m per second) = 3.93 kg per tonne.

r_0 = specific resistance of the same rake at a speed near zero = 1.82 kg per tonne.

Whence :

$$k = \frac{r_A - r_0}{v_A} = \frac{3.93 - 1.82}{15} = 0.14.$$

R_A = total resistance of the 81 type locomotive at the speed v_A = 1 106 kg.

R_0 = total resistance of the same locomotive at a speed approaching zero = 586 kg.

Whence :

$$k' = \frac{R_A - R_0}{v_A} = \frac{1\,106 - 586}{15} = 34.7$$

A. *Period of refilling the brake cylinders.*

Let us take too as in the numerical example worked out in the April 1948 *Bulletin* that :

1) the time taken to refill the brake cylinders is 55 seconds;

2) the total pressure of the brake blocks on the tyres of the braked wheels in the train can reach at the end of the time 200 000 kg;

3) the exponent n can be taken as equal to 2.5.

Having regard to the above, the constants applicable during the filling period have the following values :

$$T = 55 \text{ seconds}$$

$$n = 2.5$$

$$Q = 200\,000 \text{ kg}$$

$$A = aQ = 0.27 \times 200\,000 = 54\,000 \text{ kg}$$

$$B = bQ = 0.0072 \times 200\,000 = 1\,440 \text{ kg}$$

$$C = kP' + k'$$

$$= (0.14 \times 1\,200) + 34.7$$

$$= 202.7$$

$$= \text{or } 203 \text{ kg}.$$

First section.

Value of the constants :

Length = 550 m.

Constant slope $i_0 = i_1 = -5$ mm per m.

$K = 0$.

$K' = i_0P = i_1P = (-5) \times 1\,312 = -6\,560$ kg.

$$D = D'$$

$$= r_0 P' + R_0 + i_0 P$$

$$= (1.82 \times 1\,200) + 586 - 6\,560$$

$$= 2\,184 + 586 - 6\,560$$

$$= 2\,770 - 6\,560$$

$$= -3\,790 \text{ kg}.$$

Let us take four cuts each of 10 seconds.

First 10 *second cut.*

$T_0 = 0$, so that $\Theta = T - T_0 = T - 0 = T = 55$ seconds

$v_0 = v_1 = 15$ m per second.

$$F'(o) = -\frac{1}{M}\{Cv_0 + D'\}$$

$$= -\frac{7}{10^6}\{(203 \times 15) - 3790\}$$

$$= +\ 0.005215$$

$$F''(o) = -\frac{1}{M}\left\{\frac{n(a - bv_0)Q}{T} + CF'(o)\right\}$$

$$= -\frac{7}{10^6}\left\{\frac{2.5 \times (0.27 - 0.0072 \times 15) \times 200\ 000}{55} + 203 \times (+\ 0.005215)\right\}$$

$$= -\ 0.0103165$$

In the case of $T_1 = 10$ seconds, the equations (1) and (2) give :

$$L_1 = v_1 T_1 + F'(o)\frac{T^2_1}{2} + F''(o)\frac{T^3_1}{6}$$

$$= 15 \times 10 + 0.005215 \times \frac{\overline{10}^2}{2} - 0.0103165 \times \frac{\overline{10}^3}{6}$$

$$= \mathbf{148}.5410 \text{ metres.}$$

$$v_2 = v_1 + F'(o)\ T_1 + F''(o)\ \frac{T^2_1}{2}$$

$$= 15 + 0.005215 \times 10 - 0.0103165 \times \frac{\overline{10}^2}{2}$$

$$= \mathbf{14}.5363 \text{ metres per second.}$$

Second 10 second cut.

$T_0 = 10$ seconds, so that $\Theta = T - T_0 = 55 - 10 = 45$ seconds.

$v_0 = v_1 = \mathbf{14}.5363$ metres per second.

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{\Theta^n}{T^n}\right)Q + Cv_0 + D'\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 14.5363)\left(1 - \frac{45^{2.5}}{55^{2.5}}\right) \times 200\ 000 + 203 \times 14.5363 - 3790\right\}$$

$$= -0.086716$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n}Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right]F'(o)\right\}$$

$$= -\frac{7}{10^6}\left\{2.5\,(0.27 - 0.0072 \times 14.5363) \times \frac{45^{1.5}}{55^{2.5}} \times 200\ 000 + \left[203 - 1440\left(1 - \frac{45^{2.5}}{55^{2.5}}\right)\right] \times (-0.086716)\right\}$$

$$= -0.0077329$$

For $T_1 = 10$ seconds the equations (1) and (2) give :

$$L_1 = v_1T_1 + F'(o)\frac{T^2_1}{2} + F''(o)\frac{T^3_1}{6}$$

$$= 14.5363 \times 10 - 0.086716 \times \frac{10^2}{2} - 0.0077329 \times \frac{10^3}{6}$$

$$= \mathbf{139}.7382 \text{ metres.}$$

$$v_2 = v_1 + F'(o)T_1 + F''(o)\frac{T^2_1}{2}$$

$$= 14.5363 - 0.086716 \times 10 - 0.0077329 \times \frac{10^2}{2}$$

$$= \mathbf{13}.2825 \text{ metres per second.}$$

Third 10 *second cut.*

$T_0 = 20$ seconds, so that $\Theta = T - T_0 = 55 - 20 = 35$ seconds.

$v_0 = v_1 = 13.2825$ metres per second.

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{\Theta^n}{T^n}\right)Q + Cv_0 + D'\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 13.2825)\left(1 - \frac{\overline{35}^{2.5}}{\overline{55}^{2.5}}\right) \times 200\ 000 + 203 \times 13.2825 - 3790\right\}$$

$$= -0.15834$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n}\ Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right]F'_0\right\}$$

$$= -\frac{7}{10^6}\left\{2.5(0.27 - 0.0072 \times 13.2825) \times \frac{\overline{35}^{1.5}}{\overline{55}^{2.5}} \times 200\ 000 + \left[203 - 1440\left(1 - \frac{\overline{35}^{2.5}}{\overline{55}^{2.5}}\right)\right] \times (-0.15834)\right\}$$

$$= -0.006403$$

For $T_1 = 10$ seconds, the equations (1) and (2) give :

$$L_1 = v_1 T_1 + F'(o)\frac{T^2_1}{2} + F''(o)\frac{T^3_1}{6}$$

$$= 13.2825 \times 10 - 0.15834 \times \frac{\overline{10}^2}{2} - 0.006403 \times \frac{\overline{10}^3}{2}$$

$$= \mathbf{123}.8406 \text{ metres.}$$

$$v_2 = v_1 + F'(o)\,T_1 + F''(o)\frac{T^2_1}{2}$$

$$= 13.2825 - 0.15834 \times 10 - 0.006403 \times \frac{\overline{10}^2}{2}$$

$$= \mathbf{11}.379 \text{ metres per second.}$$

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CONTENTS OF THE NUMBER FOR FEBRUARY 1951.

1951 **625** .251
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 53.
HENNIG (E.). — Research into a method of **calculating the stopping distance in the case of goods trains retarded by continuous compressed air brakes,** with progressive charging of the brake cylinders *(Continuation and end)* (5 000 words & fig.).

1951 **625** .233 (493)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 73.
MICHOTTE (M.) and UYTBORCK (E.). — **Lighting coaches by fluorescent tubes** using 72 Volts D. C. (1 500 words & fig.).

1951 **621** .131.3 (42)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 82.
Testing new locomotives of the London, Midland & Scottish Railway (Great Britain) on the line (1 200 words & fig.)

1951 **625** .231 (45)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 85.
New rolling stock of the Italian State Railways. (1 700 words & fig.)

1951 **621** .438 (73)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 90.
YELLOTT (John I.). — The experimental **coal-burning gas turbine.** (2 500 words & fig.)

1951 **621** .438 (42)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 96.
British Railways **first gas-turbine locomotive.** (6 000 words & fig.)

1951 **625** .113
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 110.
NEW BOOKS AND PUBLICATIONS. — SCHRAMM (G). — **Bogengestaltung und Bogenabsteckung** *(The constitution of curves and their layout on site)*. (400 words.)

1951 **385** (09 (45)
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 111.
NEW BOOKS AND PUBLICATIONS. — **Le Ferrovie italiane dello State** *(La reconstruzione alla fine del 1949). (The Italian State Railways. — Their reconstruction at the end of 1949)*. (600 words.)

1951 **621** .332
Bull. of the Int. Ry. Congress Ass., No. 2, Febr., p. 112.
NEW BOOKS AND PUBLICATIONS. — **Calculo, planos de construcción y ensayos de una linea catenaria para electrificación de ferrocarriles** *(Calculation, constructional plans and tests for an overhead line for electric railways)*. (600 words.)

Fourth 10 *second cut.*

$T_0 = 30$ seconds, so that $\Theta = T - T_0 = 55 - 30 = 25$ seconds.

$v_0 = v_1 = 11.379$ metres per second.

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{\Theta^n}{T^n}\right)Q + Cv_0 + D'\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 11.379)\left(1 - \frac{\overline{25}^{2.5}}{\overline{55}^{2.5}}\right) \times 200\,000 + 203 \times 11.379 - 3790\right\}$$

$$= -0.236971$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n}Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right]F'(o)\right\}$$

$$= -\frac{7}{10^6}\left\{2.5 \times (0.27 - 0.0072 \times 11.379)\frac{25^{1.5}}{55^{2.5}} \times 200\,000 + \left[203 - 1440\left(1 - \frac{\overline{25}^{2.5}}{\overline{55}^{2.5}}\right)\right] \times (-0.236971)\right\}$$

$$= -0.00538524$$

For $T_1 = 10$ seconds, the equations (1) and (2) give :

$$L_1 = vT_1 + F'(o)\frac{T^2_1}{2} + F''(o)\frac{T^3_1}{6}$$

$$= 11.379 + 10 - 0.236971 \times \frac{\overline{10}^2}{2} - 0.0053852 \times \frac{\overline{10}^2}{6}$$

$$= \mathbf{101}.0437 \text{ metres.}$$

$$v_2 = v_1 + F'(o)T_1 + F''(o)\frac{T^2_1}{2}$$

$$= 11.379 - 0.236971 \times 10 - 0.0053852 \times \frac{\overline{10}^2}{2}$$

$$= \mathbf{8}.74 \text{ metres per second.}$$

We conclude from the above that after $4 \times 10 = 40$ seconds after the start of the brake application, the speed of the train has fallen to 8.74 m per second and that during these 40 seconds, the train has travelled :

$= \mathbf{148}.5410 + \mathbf{139}.7382 + \mathbf{123}.8406 + \mathbf{101}.0437 = \mathbf{513}.1635$ m.

The head of the train has therefore to travel before it reaches the end of the section considered a distance of :

$550 - 513.1635 = \mathbf{36}.8365$ m.

We now have to determine the time the head of the train takes to travel this distance :

Fifth and last cut of the first « section ».

For this cut :

$T_0 = 40$ seconds, whence $\Theta = T - T_0 = 55 - 40 = 15$ seconds

$v_0 = v_1 = 8.74$ m per second.

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{\Theta^n}{T^n}\right)Q + Cv_0 + D'\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 8.74)\left(1 - \frac{15^{2.5}}{55^{2.5}}\right)\right.$$

$$\left. + 203 \times 8.74003 - 3790\right\}$$

$$= -0.26438734$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n}Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right]F'(o)\right\}$$

$$= -\frac{7}{10^6}\left\{2.5(0.27 - 0.0072 \times 8.74)\frac{15^{1.5}}{55^{2.5}} \times 200\ 000\right.$$

$$\left. + \left[203 - 1440\left(1 - \frac{15^{2.5}}{55^{2.5}}\right)\right] \times (-0.26438734)\right\}$$

$$= -0.0040694122$$

The time (T_1) the head of the train takes to travel these **36**.8365 m can be found by equation (1) :

$$L_1 = v_1 T_1 + F'(0)\frac{T^2_1}{2} + F''(0)\frac{T^3_1}{6}$$

in which :

$$36.8365 = 8.74\ T_1 - 0.26438734\ \frac{T^2_1}{2} - 0.0040694122\ \frac{T^3_1}{6}$$

which gives :

$$T_1 = \mathbf{4}.5 \text{ seconds.}$$

As a check had the distance **36**.8365 m been run over by the head of the train at a constant speed of $v_1 = \mathbf{8}.74$ m per second, the corresponding time would not have exceeded :

$$\frac{36.8365}{8.74} = \mathbf{4}.218 \text{ seconds}$$

a value necessarily lower than that of **4**.5 seconds taken when the speed is decreasing.

The speed v_2 of the train at the end of these **4**.5 seconds, i. e. when the head of the train passes out of the section is given by equation (2) :

$$v_2 = v_1 + F'(o)T_1 + F''(o)\frac{T^2_1}{2}$$

$$= 8.74 - 0.26438734 \times 4.5 - 0.0040694122 \times \frac{\overline{4.5^2}}{2}$$

$$= \mathbf{7}.5091 \text{ metres per second.}$$

The distance travelled of 550 m (length of the first section) has therefore taken 40 + 4.5 = **44**.5 seconds and, at the end of this distance, the speed has dropped to 7.5091 m per second).

Second « section ».

Values of the constants.

1) Length = 18 m.

2) $v_0 = v_1 = 7.5091$ m per second.

3) $T_0 = \mathbf{44}.5$ seconds, so that $\Theta = T - T_0 = 55 - 44.5 = 10.5$ seconds.

4) $iP = K\,l + K'$

$$K = (i_2 - i_1)\,p_1$$
$$= [\,-2 - (-5)\,] \times 6.222$$
$$= (-2 + 5) \times 6.222$$
$$= (+3) \times 6.222$$
$$= +18.666 \text{ kg per metre run over.}$$

$$K' = i_1 P$$
$$= (-5) \times 1312$$
$$= -6560 \text{ kg.}$$

5) $D = r_0\,P' + R_0 + K'$

$$= 2770 - 6560$$
$$= -3790 \text{ kg.}$$

Under these circumstances for the section under consideration :

$$F'(o) = -\frac{1}{M}\left\{(a - bv_0)\left(1 - \frac{\Theta^n}{T^n}\right)Q + Cv_0 + D\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 7.5091)\left(1 - \frac{\overline{10.5}^{2.5}}{\overline{55}^{2.5}}\right) \times 200\ 000 + 203 \times 7.5091 - 3790\right\}$$

$$= -0.2817$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n}Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right]F'(o) + Kv_0\right\}$$

$$= -\frac{7}{10^6}\left\{2.5(0.27 - 0.0072 \times 7.5091)\frac{\overline{10.5}^{1.5}}{\overline{55}^{2.5}} \times 200\ 000 + \left[203 - 1440\left(1 - \frac{\overline{10.5}^{2.5}}{\overline{55}^{2.5}}\right)\right] \times (-0.2817) + 18.666 \times 7.5091\right\}$$

$$= -0.002338$$

Equation (1) gives :

$$18 = 7.5091\ T_1 - 0.2817\ \frac{T^2_1}{2} - 0.002338\ \frac{T^3_1}{6}$$

and gives $T_1 = 2.5$ seconds.

The check : $\frac{18}{7.5091} = 2.397$ seconds $<$ 2.5 seconds.

The equation (2) then gives :

$$v_2 = 7.5091 - 0.2817\ T_1 - 0.002338\ \frac{T^2_1}{2}$$

$$= 7.5091 - 0.2817 \times 2.5 - 0.002338 \times \frac{\overline{2.5}^2}{2}$$

$= 6.7319$ metres per second.

The 18 m section is travelled over by the head of the train in 2.5 seconds and when it reaches the end of the section the speed has fallen to 6.7319 m per second. At this moment the distance travelled since braking started equals 550 + 18 = 568 m and the time 44.5 + 2.5 = 47 seconds.

Third « section ».

This 500 m length (the length of the rake) bridges the end of the recharging period and the beginning of the period of braking at constant pressure.

We have now to calculate the distance the head of the train travels during these 55 — 47 = 8 seconds from entering the third section to the instant the period of recharging the brake cylinders ends. The speed the train reaches at this moment has also to be ascertained.

The constants for the part of the section considered are the following :

1) Time of run = 8 seconds.

2) v_1 = 6.7319 m per second.

3) T_0 = 47 seconds so that $\Theta = T - T_0 = 55 - 47 = 8$ seconds.

4) $iP = Kl + K'$

$K = (i_2 - i_1)\, p'$

$= [\, -2 - (-5)\,]\, 2.4$

$= (-2 + 5)\, 2.4$

$= (+3) \times 2.4$

$= +7.2$ kg per m run of the distance travelled.

$K' = i_1 P' + i_2 P_1$

$= (-5) \times 1200 + (-2) \times 112$

$= -6000 - 224$

$= -6224$ kg

$D = r_0 P' + R_0 + K'$

$= 2770 - 6224$

$= -3454$ kg.

Under these conditions for the part of the section considered :

$$F'(o) = -\frac{1}{M}\left\{\left(a - bv_0\right)\left(1 - \frac{\Theta^n}{T^n}\right) Q + Cv_0 + D\right\}$$

$$= -\frac{7}{10^6}\left\{(0.27 - 0.0072 \times 6.7319)\left(1 - \frac{8^{2.5}}{55^{2.5}}\right) \times 200\,000 + 203 \times 6.7319 - 3454\right\}$$

$$= -0.2929857$$

$$F''(o) = -\frac{1}{M}\left\{n(a - bv_0)\frac{\Theta^{n-1}}{T^n} Q + \left[C - bQ\left(1 - \frac{\Theta^n}{T^n}\right)\right] F'(o) + Kv_0\right\}$$

$$= -\frac{7}{10^6}\left\{2.5(0.27 - 0.0072 \times 6.7319)\frac{8^{1.5}}{55^{2.5}} \times 200\,000 + \left[203 - 1440\left(1 - \frac{8^{2.5}}{55^{2.5}}\right)\right] \times (-0.2929857) + 7.2 \times 6.7319\right\}$$

$$= -0.0036275$$

Whence the speed at the end of the recharging period :

$$v_D = 6.7319 - 0.2929857 \times 8 - 0.0036275 \times \frac{8^2}{2}$$

$= 4.272$ m per second and the distance travelled during these 8 seconds :

$$= 6.7319 \times 8 - 0.2929857 \times \frac{\overline{8^2}}{2} - 0.0036275 \times \frac{\overline{8^3}}{6}$$

$= \mathbf{44}.1714$ metres.

Checking : $\frac{6.7319 + 4.272}{2} \times 8 = 44$ metres < 44.1714 metres.

***

At the end of the recharging period the speed has therefore fallen to 4.272 m per second and the train has travelled during the 55 seconds of the period $568 + \mathbf{44}.1714 = \mathbf{612}.1714$ m.

It may be remembered that in the previous investigation (first part), we found that for the same train braked under the same conditions on a continuous down gradient of 5 °/₀₀ :

$v_B = \mathbf{4}.89$ m per second.

L = 620 m.

B. *Period of braking at constant pressure.*

In the present case, it will be noted that this period begins at the moment when the head of the train has already travelled over the third section a distance of :

$$l_0 = \mathbf{44}.1714 \text{ m}$$

from the beginning of this section represented by the equation :

$$iP = 7.2\ l - 6224$$

At this moment, the speed of the train is : $v_B = \mathbf{4}.272$ m per second.

The train naturally should stop well before its head gets to the end of the section, which is situated at a distance of :

$\mathbf{500} - \mathbf{44}.1714 = \mathbf{455}.8286$ m ahead.

To ascertain the distance of the third section l'_1 still to be run over by the head of the train from the beginning of the period considered to the stop, this will be given by the differential equation VI :

$$v \frac{dv}{dl'} = - \left\{ Av + Bl' + C \right\}$$

in which :

— the constant $A = \dfrac{kP' + k' - bQ}{M}$

$$= \frac{(0.14 \times 1200) + 34.7 - 144_0}{144436}$$

$$= \frac{168 + 34.7 - 1440}{144436}$$

$$= \frac{202 - 1440}{144436}$$

$$= - \frac{1237.3}{144436}$$

$$= - 0.00856$$

— the constant $B = \dfrac{K}{M} = \dfrac{7.2}{144436} = 0.00005$

— the constant $C' = \dfrac{aQ + r_0 P' + R_0 + K l_0 + K'}{M}$

$$= \frac{(0.27 \times 200\,000) + (1.82 \times 1200) + 586 + (7.2 \times 44.1714) - 6224}{144436}$$

$$= \frac{54000 + 2184 + 586 + 318 - 6224}{144436}$$

$$= \frac{50\ 864}{144436}$$

We find that :

$$\frac{A^2}{4} - B = \frac{\overline{0.00856}^2}{4} - 0.00005$$

$$= 0.0000183184 - 0.00005$$

$$=$$ a negative value.

Then making : $\Theta = \sqrt{B - \frac{A^2}{4}}$

$$= \sqrt{0.00005 - 0.0000183184}$$

$$= \sqrt{0.0000316816}$$

$$= 0.0056286$$

Under these conditions and as the section considered overlaps the two periods, the final distance of the stop (l'_1) is given by equation **20** :

$$\log_n \left(l'_1 + \frac{C'}{B}\right) - \log_n \frac{C'}{B} = \frac{1}{2} \log_n \frac{\left(\frac{Bv_1}{C'} + \frac{A}{2}\right) + \Theta^2}{\frac{A^2}{4} + \Theta^2} - \frac{A}{2\Theta} \text{ arc tg } \frac{\Theta \frac{Bv_1}{C'}}{\Theta^2 + \left(\frac{Bv_1}{C'} + \frac{A}{2}\right)\frac{A}{2}}$$

in which :

$$\frac{C'}{B} = \frac{50864}{7.2} = 7064.4$$

$$\frac{Bv_1}{C'} = \frac{v_1}{\frac{C'}{B}} = \frac{4.272}{7064.4} = 0 \ .00064$$

$$\frac{A}{2} = -\frac{0.00856}{2} = -0.00428$$

$$\Theta^2 = 0.0000316816$$

$$\frac{A^2}{4} = 0.0000183184$$

$$\frac{A}{2\Theta} = -\frac{0.00856}{2 \times 0.0056286} = -0.7604$$

so that :

$$\log_n (l'_1 + 7064.4) = \log_n 7064.4$$

$$+ \frac{1}{2} \log_n \frac{(0.00064 - 0.00428)^2 + 0.0000316816}{0.0000183184 + 0.0000316816}$$

$$+ 0.7604 \text{ arc tg} \frac{0.0056286 \times 0.00064}{0.0000316816 - (0.00064 - 0.00428) \times 0.00428}$$

or :

$$\log_n (l'_1 + 7064.4) = \log_n 7064.4 + \frac{1}{2} \log_n 0.8986 + 0.7604 \text{ arc tg } 0.076$$

or, noting that : arc tg $0.076 = 4^0 20'$ or $4^0, 33$

$$= \frac{\pi \times 4.33}{180} \text{ radians}$$

$$= 0.075573 \text{ radians}$$

and that $\log_n N = 2.3026 \log N$:

$$2.3026 \log (l'_1 + 7064.4) = 2.3026 \log 7064.4$$

$$+ \frac{1}{2} \times 2.3026 \log 0.8986$$

$$+ 0.7604 \times 0.075573$$

or, finally :

$$2.3026 \log (l'_1 + 7064.4) = 2.3026 \times 3.8490753$$

$$+ \left(\frac{1}{2} \times 2.3026 \times (- 0.0464336) \right)$$

$$+ (0.7604 \times 0.075573)$$

$$= 8.86288078578$$

$$- 0.053459$$

$$+ 0.0574657092$$

$$= 8.86688749498$$

whence :

$$\log(l'_1 + 7064.4) = \frac{8.86688749498}{2.3026}$$

$$= 8.86688749498 \times 0.4343$$

$$= 3.850889239$$

$$= \log \text{ de } 7093.9$$

Therefore :

$$l'_1 + 7064.4 = 7093.9$$

So that finally :

$$l'_1 = 7093.9 - 7064.4 = \mathbf{29}.5 \text{ metres.}$$

As to the corresponding time, equation (30) gives :

$$t'_1 = \frac{1}{\Theta} \text{ arc tg} \frac{\Theta \dfrac{Bv_1}{C'}}{\Theta^2 + \left(\dfrac{Bv_1}{C'} + \dfrac{A}{2}\right)\dfrac{A}{2}}$$

$$= \frac{1}{0.0056286} \times 0.075573$$

$$= 177.664 \times 0.075573$$

$$= \mathbf{13}.4266$$

$$= \text{soit } \mathbf{13}.4 \text{ seconds}$$

Checking : $\frac{4.272}{2} \times 13.4266 = 28.6792$ metres, a value necessarily smaller than 29.5 metres.

Conclusion.

In the example here dealt with the total stopping distance of the train then becomes :

$$= 612.2 + 29.5$$

$$= \mathbf{641}.7 \text{ m}$$

and the time the train takes to travel it :

$$= 55 + 13.4$$

$$= \mathbf{68}.4 \text{ seconds.}$$

These figures could be compared with those found before (see *Bulletin*, April

1948) for the case of the same train braked down a constant gradient of 1 in 200, to wit :

Distance travelled = **657**.9 m.

Time taken = **70**.6 seconds.

Addendum.

The following example illustrates a less simple case than that considered above.

Let us suppose a goods train of a total weight P tonnes and a total length of L metres made up of :

— At the head of the train one or two locomotives weighing P_1 tonnes, and l_1 m long.

— The body of the train formed of a rake of wagons weighing P′ tonnes of L′ m length.

— At the tail of the train one or two locomotives weighing P_2 tonnes, and l_2 m long.

The quantities P and L have the value :

$$P = P_1 + P' + P_2$$

$$L = l_1 + L' + l_2$$

Let us take :

— p_1 tonnes the weight per metre run of the locomotives at the head of the train;

we shall have $p_1 = \frac{P_1}{l_1}$.

— p' tonnes the weight per metre run of the rake of wagons when

$p' = \frac{P'}{L'}$.

— p_2 tonnes the weight per metre run of the locomotives at the tail when

$p_2 = \frac{P_2}{l_2}$.

Let us allow that at the start of braking the position is as shown in fig. 8 :

— A portion (at the tail of the train) of length L_1 m is on a section of which the slope is i_1 mm per m, this portion consisting of P_2 tonnes of locomotives and $(L_1 - l_2)\ p'$ tonnes of wagons.

— A portion (of the body of the rake) of length L_2 m on a section of slope i_2 mm per m, this portion consisting of $L_2 p'$ tonnes of wagons.

— A portion (at the head of the train) of length L_3 m on a slope of i_3 mm per m, this portion comprising $(L_3 - l_1)p'$ tonnes of wagons and P_1 tonnes of locomotives.

In other terms :

$$l_1 + L' + l_2 = L_1 + L_2 + L_3 = L$$

Let us consider the train in the successive positions I to IX (fig. 8).

The numerical values of the inclinations i_1, i_2 and i_3 being taken with their respective signs (the sign + for up gradients and the sign — for the down gradients in the direction of running), the following relations can be written :

1) At the beginning of the braking the train being in position I :

$$iP = i_1P_2 + i_1p'(L_1 - l_2) + i_2p'L_2 + i_3p'(L_3 - l_1) + i_3P_1$$
$$= i_1\{P_2 + p'(L_1 - l_2)\} + i_2p'L_2 + i_3\{p'(L_3 - l_1) + P_1\}$$

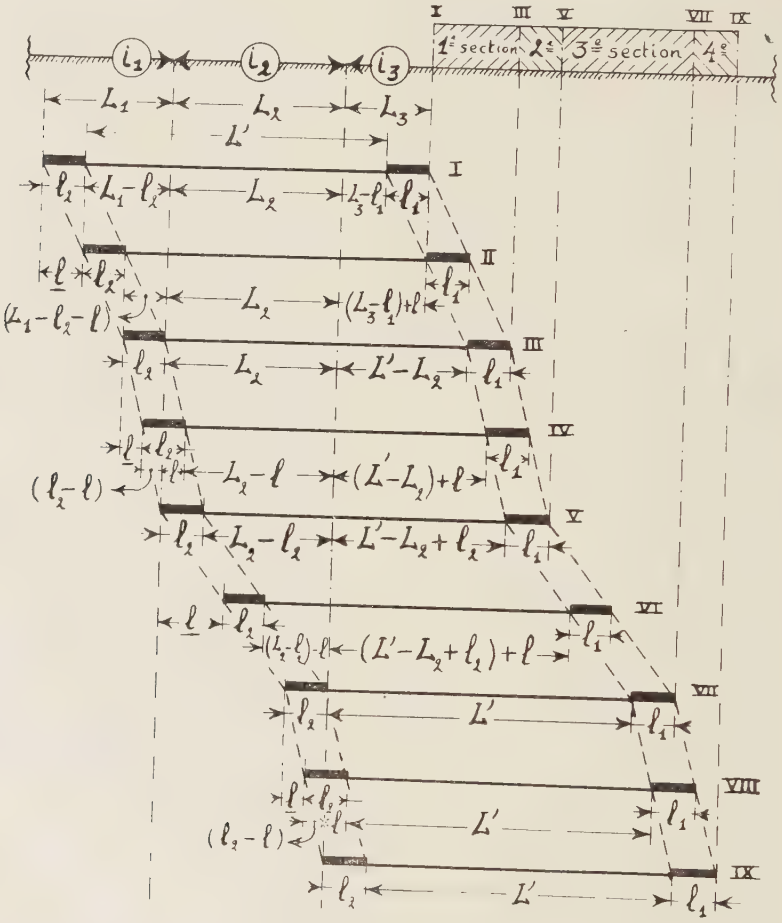


Fig. 8.

2) After a run of l metres from the beginning of the braking (l being at most equal to $L_1 - l_2$), the train being in position II :

$$iP = i_1P_2 + i_1p'(L_1 - l_2 - l) + i_2p'L_2 + i_3p'(L_3 - l_1 + l) + i_3P_1$$
$$= i_1P_2 + i_1p'L_1 - i_1p'l_2 - i_1p'l + i_2p'L_2 + i_3p'L_3 - i_3p'l_1 + i_3p'l + i_3P_1$$
$$= (i_3 - i_1)p'l + i_1P_2 + i_1p'(L_1 - l_2) + i_2p'L_2 + i_3p'(L_3 - l_1) + i_3P_1$$
$$= (i_3 - i_1)p'l + i_1\{P_2 + p'(L_1 - l_2)\} + i_2p'L_2 + i_3\{p'(L_3 - l_1) + P_1\}$$

We see that when $l = L_1 - l_2$ the term iP takes the value :

$$\begin{aligned} i\mathrm{P} &= (i_3 - i_1)p'(L_1 - l_2) + i_1\mathrm{P}_2 + i_1p'(L_1 - l_2) + i_2p'L_2 + i_3p'(L_3 - l_1) + i_3\mathrm{P}_1 \\ &= i_3p'L_1 - i_1p'L_1 - i_3p'l_2 + i_1p'l_2 + i_1\mathrm{P}_2 + i_1p'L_1 - i_1p'l_2 + i_2p'L_2 + i_3p'L_3 \\ &\qquad - i_3p'l_1 + i_3\mathrm{P}_1 \\ &= i_1\mathrm{P}_2 + i_2p'L_2 + i_3p'(L_1 - l_2 + L_3 - l_1) + i_3\mathrm{P}_1 \\ &= i_1\mathrm{P}_2 + i_2p'L_2 + i_3p' \{ (L_1 + L_3) - (l_1 + l_2) \} + i_3\mathrm{P}_1 \end{aligned}$$

Noting that :

$$(L_1 + L_3) - (l_1 + l_2) = (L - L_2) - (L - L') = L' - L_2$$

we get finally :

$$i\mathrm{P} = i_1\mathrm{P}_2 + i_2p'L_2 + i_3p'(L' - L_2) + i_3\mathrm{P}_1$$

the value characterising the position III.

3) After a run of l m, made from the beginning of position III (l being at best equal to l_2) the train being in position IV :

$$\begin{aligned} i\mathrm{P} &= i_1p_2(l_2 - l) + i_2p_2l + i_2p'(L_2 - l) + i_3p' \{ (L' - L_2) + l \} + i_3\mathrm{P}_1 \\ &= (-i_1p_2 + i_2p_2 - i_2p' + i_3p')l + i_1p_2l_2 + i_2p'L_2 + i_3p'(L' - L_2) + i_3\mathrm{P}_1 \\ &= \{(i_2 - i_1)p_2 + (i_3 - i_2)p' \} l + i_1p_2l_2 + i_2p'L_2 + i_3(p'L' - p'L_2 + \mathrm{P}_1) \end{aligned}$$

Noting that $p'L' = \mathrm{P}'$ and $p_2l_2 = \mathrm{P}_2$, we get :

$$i\mathrm{P} = \{ (i_2 - i_1)p_2 + (i_3 - i_2)p' \} l + i_1\mathrm{P}_2 + i_2p'L_2 + i_3(\mathrm{P}_1 - \mathrm{P}' - p'L_2)$$

We check that for $l = l_2$, the term iP becomes :

$$\begin{aligned} i\mathrm{P} &= i_2p_2l_2 + i_2p'L_2 - i_2p'l_2 + i_3p'L' - i_3p'L_2 + i_3p'l_2 + i_3\mathrm{P}_1 \\ &= i_2\mathrm{P}_2 + i_2p'(L_2 - l_2) + i_3p'(L' - L_2 + l_2) + i_3\mathrm{P}_1 \end{aligned}$$

value characterising the position V.

4) After a run of l metres from the position V (l being at most equal to $L_2 - l_2$), the train being in position VI :

$$\begin{aligned} i\mathrm{P} &= i_2\mathrm{P}_2 + i_2p'(L_2 - l_2 - l) + i_3p'(L' - L_2 + l_2 + l) + i_3\mathrm{P}_1 \\ &= i_2\mathrm{P}_2 + i_2p'(L_2 - l_2) - i_2p'l + i_3p'(L' - L_2 + l_2) + i_3p'l + i_3\mathrm{P}_1 \\ &= (i_3 - i_2)p'l + i_2\mathrm{P}_2 + i_2p'(L_2 - l_2) + i_3p'(L' - L_2 + l_2) + i_3\mathrm{P}_1 \\ &= (i_3 - i_2)p'l + i_2 \{ \mathrm{P}_2 + p'(L_2 - l_2) \} + i_3 \{ \mathrm{P}_1 + p'(L' - L_2 + l_2) \} \\ &= (i_3 - i_2)p'l + i_2 \{ \mathrm{P}_2 + p'(L_2 - l_2) \} + i_3 \{ \mathrm{P}_1 + p'L' - p'L_2 + p'l_2 \} \\ &= (i_3 - i_2)p'l + i_2 \{ \mathrm{P}_2 + p'(L_2 - l_2) \} + i_3 \{ \mathrm{P}_1 + \mathrm{P}' - p'(L_2 - l_2) \} \end{aligned}$$

We check that for $l = L_2 - l_2$, the term iP becomes :

$$\begin{aligned} iP &= (i_3 - i_2)p'(L_2 - l_2) + i_2 \{ P_2 + p'(L_2 - l_2) \} + i_3 \{ P_1 + P' - p'(L_2 - l_2) \} \\ &= i_3 p' L - i_2 p' L_2 - i_3 p' l_2 + i_2 p' l_2 + i_2 P_2 + i_2 p' L_2 - i_2 p' l_2 + i_3 P_1 + P' - p'(L_2 - l_2) \} \\ &= i_2 P_2 + i_3 p' L_2 - i_3 p' l_2 + i_3 P_1 + i_3 P' - i_3 p' L_2 + i_3 p' l_2 \\ &= i_2 P_2 + i_3 P_1 + i_3 P' \\ &= i_2 P_2 + i_3 (P_1 + P') \end{aligned}$$

value characterising the position VII.

5) After running l metres from position VII (l being at most equal to l_2), the train in position VIII :

$$\begin{aligned} iP &= i_2 p_2 (l_2 - l) + i_3 p_2 l + i_3 (P' + P_1) \\ &= i_2 p_2 l_2 - i_2 p_2 l + i_3 p_2 l + i_3 (P' + P_1) \\ &= (i_3 - i_2) p_2 l + i_2 p_2 l_2 + i_3 (P' + P_1) \\ &= (i_3 - i_2) p_2 l + i_2 P_2 + i_3 (P' + P_1). \end{aligned}$$

Checking for $l = l_2$ the term iP becomes :

$$\begin{aligned} iP &= i_3 p_2 l_2 + i_3 (P' + P_1) \\ &= i_3 P_2 + i_3 P' + i_3 P_1 \\ &= i_3 (P_2 + P' + P_1) \\ &= i_3 P \end{aligned}$$

value characterising the position IX.

Thus in the present example we have before us the four fictive « sections » :

— A first (I-III) of length $L_1 = L_1 - l_2$, the variable inclination (i) of which is given by the relation :

$$iP = K_1 l + K'_1$$

in which :

$$K_1 = (i_3 - i_1) p'$$

$$K'_1 = i_1 \{ P_2 + p'(L_1 - l_2) \} + i_2 p' L_2 + i_3 \{ p'(L_3 - l_1) + P_1 \}$$

— A second (III-V) of length $L_2 = l_2$, the variable inclination (i) of which is shown by the relation :

$$iP = K_2 l + K_2'$$

in which :

$$K_2 = (i_2 - i_1) p_2 + (i_3 - i_2) p'$$

$$K_2' = i_2 P_2 + i_2 p' L_2 + i_3 (P_1 + P' - p' L_2)$$

— A third section (V-VII) of length $L_3 = L_2 - l_2$ the variable inclination (i) of which is shown by the relation :

$$iP = K_3 l + K'_3$$

in which :

$$K_3 = (i_3 - i_2) p'$$

$$K_3' = i_2 \{ P_2 + p'(L_2 - l_2) \} + i_3 \{ P_1 + P' - p'(L_2 - l_2) \}$$

— A fourth section (VII-IX) of length $L_4 = l_2$ of varying inclination (i) shown by the relation :

$$iP = K_4 l + K_4'$$

in which :

$$K_4 = (i_3 - i_2) p_2$$

$$K'_4 = i_2 P_2 + i_3 (P' + P_1)$$

— Finally, and eventually, a fifth section of indefinite length of which the actual slope is $= i_3$.

[625. 233 (493)]

Lighting coaches by fluorescent tubes using 72 Volts D. C.,

by M. Michotte,

Ingénieur principal adjoint à la Société Nationale des Chemins de fer belges,

and E. Uytborck,

Ingénieur à la Société Nationale des Chemins de fer belges.

I. — Preliminaries.

All up to date systems of incandescent lighting on railway rolling stock include in principle the following components (fig. 1) :

— an accumulator;

— a variable speed shunt dynamo;

— a control box containing the regulators of the generator and the lamp voltage;

— a switch.

The correct working of the equipment depends to a great extent on the precision and regularity of working of the control box. The small variations in the voltage required both in the regulation of the excitation of the generator and in that of the voltage to the lamps involve cutting in or out very progressively the resistances assuring this regulation.

For this purpose, the makers use either mercury contacts or rolling or rocking sector discs, or piles of carbon discs progressively compressed and decompressed.

These variable resistances, especially those for the lamps, naturally absorb part

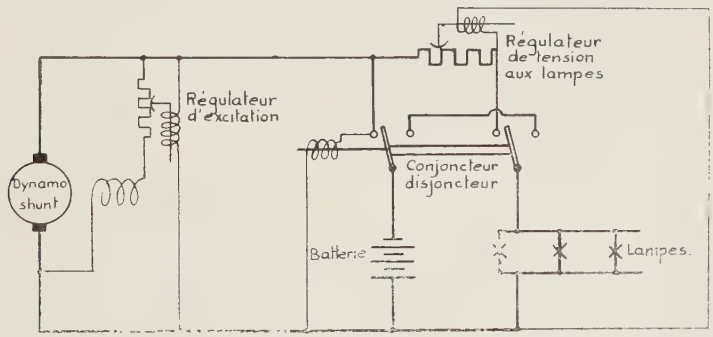


Fig. 1.

Explanation of French terms :

Batterie = Accumulator. — Régulateur de tension aux lampes = Regulator of the lamp voltage. — Régulateur d'excitation = Regulator of the generator. — Conjoncteur disjoncteur = Switch.

of the available current. It is therefore important for the nominal voltage of the lamps to lie between the limiting voltages of the battery.

II. — Fluorescent lighting.

1. *Investigations carried out with the collaboration of the makers.*

During the war the International Sleeping Car Co. investigated the use of fluorescent tubes in their restaurant cars. The decorative possibilities, the greater amount of light for the same power installed, and the long life of the tubes fully justified this investigation.

At the end of 1944, this Company equipped a restaurant car with 220 V A. C. fluorescent lighting. The A. C. current was supplied from a motor-alternator set working off the battery.

This solution, which was also adopted by some American railways, makes it impossible to use all the power available, as a part thereof is absorbed by the set (efficiency = 70 %).

Later on the S. N. C. F. carried out various similar tests and decided to use equipment consisting essentially of a set generating A. C. current at 80 periods driven off the battery or dynamo.

The S. N. C. B. whilst aware of these applications did not find them very attractive and directed its investigations towards finding a solution that at first sight seemed much simpler, viz the use of fluorescent tubes supplied with low voltage D. C. current.

A nominal voltage of 72 V was at once adopted; this enabled the tubes to light readily and was the same as the voltage used on the railcars and rail motor coaches, and finally made it possible to reduce appreciably the amperages in play.

The choice of this voltage however made it necessary to increase the number of cells in the coach batteries, and consequently the final voltage on charge (105 V for a nickel-cadmium battery); it also limited the final discharge voltage of the battery (rupturing of the tubes).

The power to be dissipated at the end of the charge by the regulator of the lights was thus appreciably increased (about 350 W for an installation of 30 tubes) and the total capacity of the battery could not be utilised during discharge.

To obtain economic fluorescent lighting with direct current, clearly it would be necessary to suppress the lighting regulator and stabilise, even at a low temperature (-5°) the tubes between 60 and 105 V by a static device based on the negative characteristic of the tube, so as to obtain a robust installation with tubes and static stabilisation gear with a life of at least 2 000 hours.

Such was the problem put before the A.C.E.C. (*) and to the Philips works. In collaboration with these firms, investigations were rapidly completed which led to the construction of a new prototype meeting our requirements.

2. *Prototype equipment.*

The lighting equipment of an S.N.C.B. metal coach using 72 V D. C. fluorescent

(*) Ateliers de Constructions Electriques de Charleroi - Belgium.

tubes consists of the following parts (fig. 2) :

— a 72/105 V, 35 or 40 amp. dynamo;

— a control box for the dynamo with a circuit breaker;

— a 72 V, 85 amp./h. battery;

— 30-15 W tubes working without starter or inductor coil.

francs; with A. C. the price would be about 88 000 Belgian francs.

3. *The 72 V fluorescent tube.*

In the present state of technical knowledge, it is not possible to get fluorescent tubes of more than 14 or 15 W working properly with 72 V D. C.

The principle now perfected by the

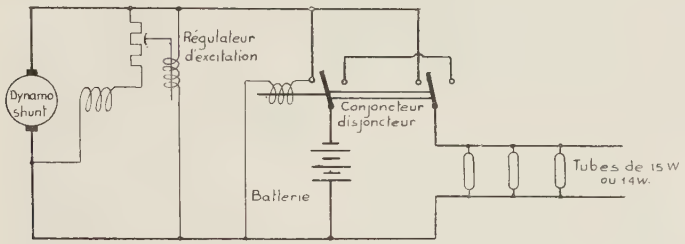


Fig. 2.

Explanation of French terms :

Batterie Accumulator. — Régulateur d'excitation = Regulator of the generator. — Conjoncteur disjoncteur = Switch. — Tubes de 14 W ou 15 W = 14 or 15 W tubes.

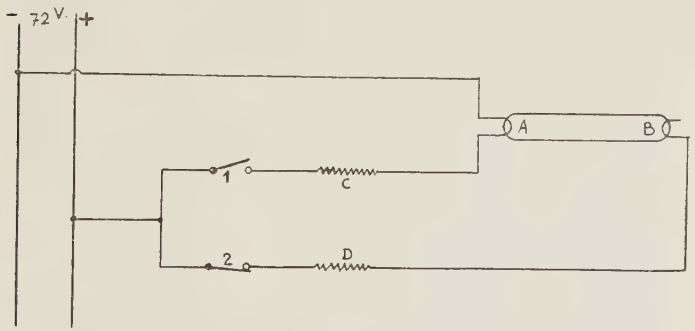


Fig. 3.

The present cost of this equipment complete and in working order (including the cabling and protective hoods for the tubes) is 74 000 Belgian francs. 24 V incandescent lighting, giving a poorer light, would cost 90 000 Belgian

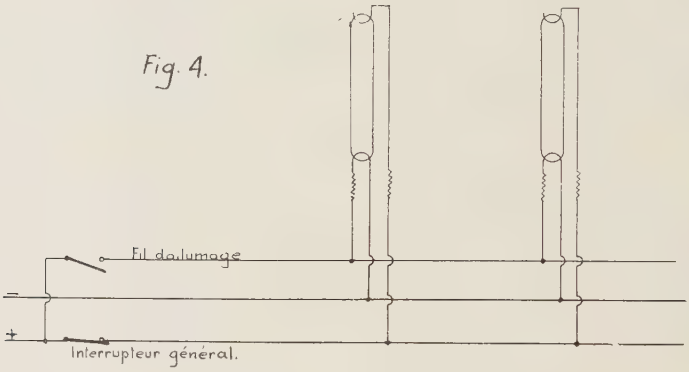
above mentioned firms for supplying direct current to 14 or 15 W tubes is completely different from that used in the case of alternating current. Each of the two electrodes is normally connected to one pole of the 72 V battery (fig. 3).

By itself this voltage is insufficient to light up the tube.

By closing the circuit-breaker 1 for a short period, the preheating current runs through the electrode A. This current, limited by the resistance C heats the filament A and causes the tube to light up. The circuit-breaker 1 is then returned to the open position, cutting off the preheating current.

After it has been lit, the current in the tube is limited by the resistance D.

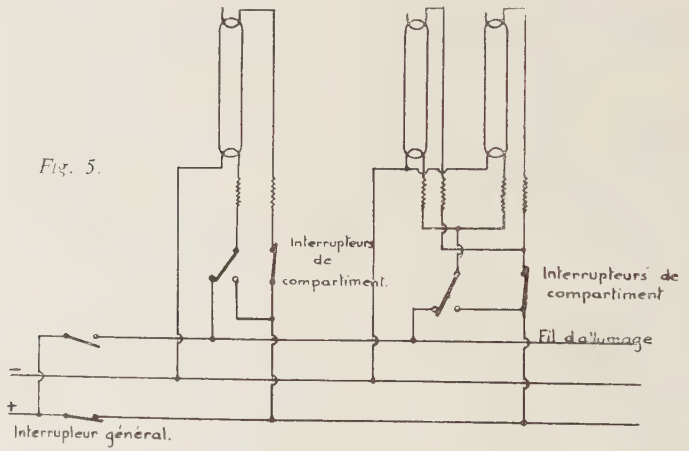
Fig. 4.



Explanation of French terms :

Fil d'allumage = Lighting wire. — Interrupteur général = General switch.

Fig. 5.



Explanation of French terms :

Interrupteur général = General switch. — Interrupteur de compartiment = Compartment switch. — Fil d'allumage = Lighting wire.

The tube is put out by opening the circuit-breaker 2 for a moment. After it has gone out, this circuit breaker can be closed without the tube lighting up

again. The resistances C and D are incorporated in a small lamp which is the only auxiliary electric component of the tube.

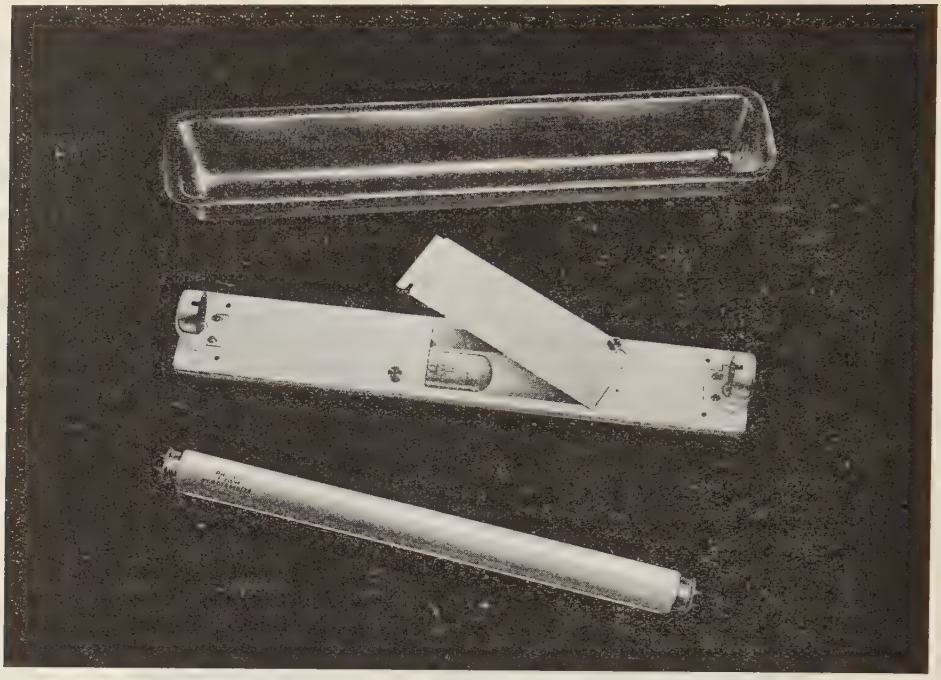
If it is wished to let the train staff control the general lighting of the coach by means of a single switch, a third wire, known as the lighting wire, is used.

Fig. 6.

This arrangement has the advantage of making it possible to get immediate lighting up, even just after the tubes have been put out.

Fig. 4 gives a diagram of such an installation.

It is also possible to combine the general lighting with separate control of



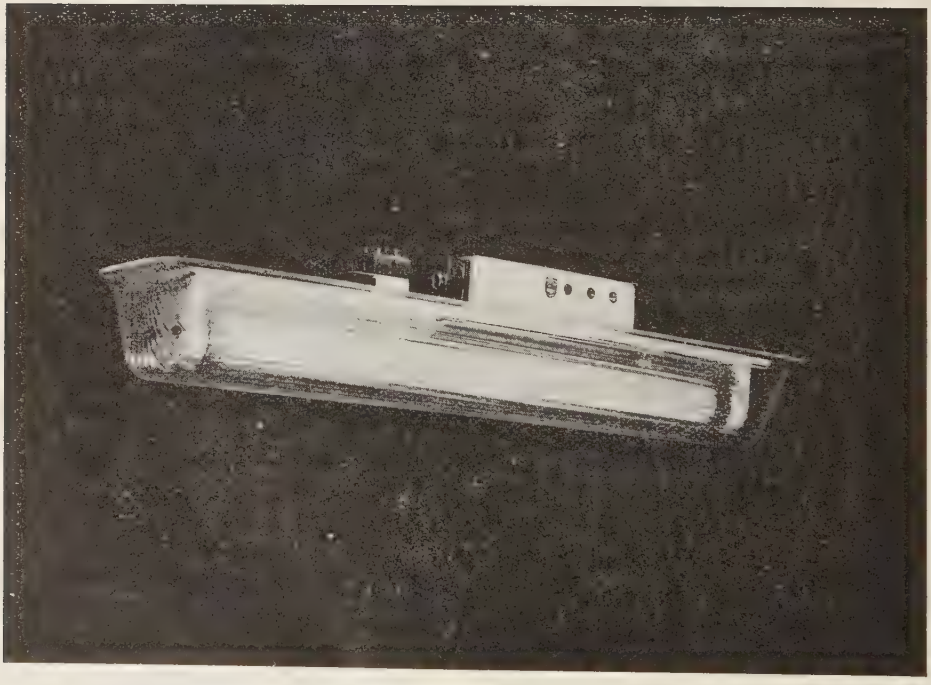


Fig. 7.

each tube or group of tubes (fig. 5), this being the standard practice on the international coaches where the lighting of each compartment can be controlled separately.

The characteristics of the lamps in which the resistances C and D are incorporated make it possible to feed the installation at voltages varying between 60 and 105.

The equipment works correctly with a commercial 14 or 15 W tube designed for alternating current.

However to prevent premature blackening of the ends of the tube, the makers have been led to manufacture tubes with special filaments which do not require periodic inversion of the polarity.

For aesthetic reasons, the S. N. C. B. selected tubes whose t° of colour lies between 2 500° K and 2 900° K.

After 100 hours running, the 72 V equipment has the following characteristics :

Fig. 8.

	14 W	*15 W*
Luminous flux in lumens	490	600
Total consumption of equipment in watts	27	24
Light output lumen/watt	18	25

Intensity of current in ordinary work : A .	0.37	0.335
Intensity of current at rupture : A . . .	0.70	0.70
Voltage of electric arc : V	38	45

tubes and stabilising lamps is at least 2 000 hours.

For the outer limits of the working voltages of 60 to 105 V, the current and luminous flux varies approximately — 5 % + 12 %.

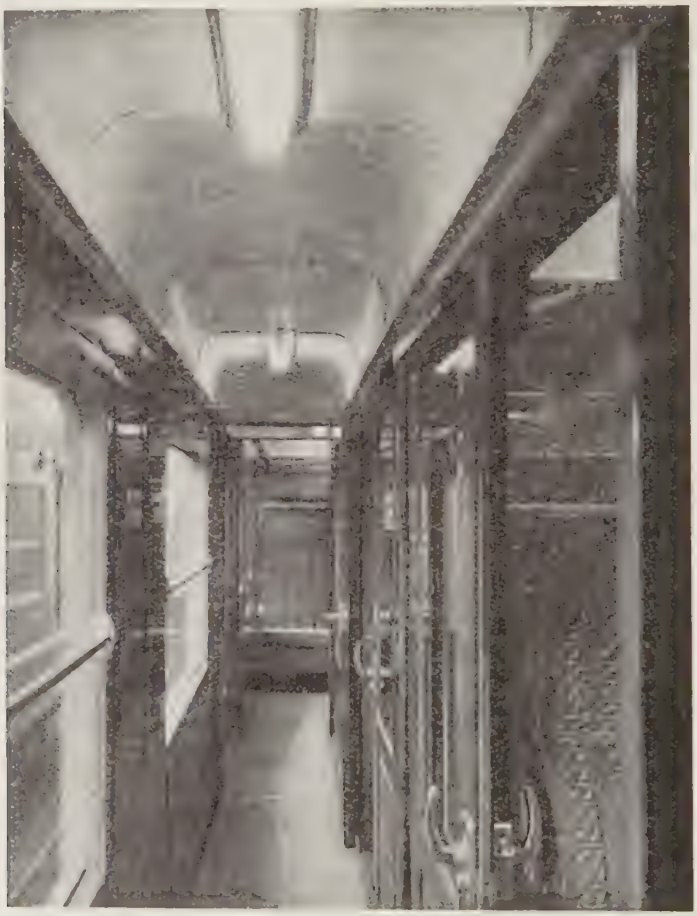


Fig. 9.

After 1 500 hours work, the luminous flux falls to 400 lumens for the 14 W tubes and 500 for the 15 W.

The average guaranteed life of the

The 15 W tube is obviously the most attractive both from the point of view of consumption and of light output.

The S. N. C. B. has already ordered

fluorescent lighting equipment based on the above principles for 25 double electric rail motor coaches which are to be put into service in the summer of 1950.

It has also been decided to equip 100 other coaches (50 of which are RIC) and 60 railcars.

4. *Applications.*

A. — A double electric rail motor coach has been equipped with fifty-five 14 W sets manufactured by the A.C.E.C. working at 72 V.

Each 40 W lamp in the 3rd class carriages, vestibules and W. C. has been replaced by a tube, and each 60 W lamp in the 2nd class carriages by 2 tubes side by side.

The tubes are protected by a ribbed plastic transparent colourless hood, with an absorbant power of approximately 10 %.

The average lighting of the seats at horizontal reading level (1 m = 3′ 3 3/8″ above floor level) and 0.4 m (1′ 3 3/4″) away from the back of the seat is :

	Incandescent	*Fluorescent*
2nd class	48 lux	150 lux
3rd class	34 lux	79 lux

Fig. 6 shows the inside of a 2nd class compartment.

B. — A 22 m (72′ 2 1/8″) metal coach (1st-2nd classes) was equipped with forty 15 W sets manufactured by S. A. Philips working at 72 V.

Each 40 W lamp in the 2nd class compartments has been replaced by two tubes side by side. In the 1st class compartments, 3 tubes have been used in place of one 40 W lamp and the four 25 W reading lamps.

Tubes have also been fitted in the vestibules, corridors and W. C.

The tubes are protected by a plastic hood similar to those used in the double rail motor coach.

The average lighting of the seats at reading level (1 m above floor level) and 0.40 m from the back of the seat is :

	Incandescent	*Fluorescent*
2nd class	37.5 lux	172 lux
1st class	32 lux	99 lux

The tube assembly is shown in fig. 7.

Figures 8 and 9 are photographs showing a 2nd class compartment and the corridor respectively.

[621 .131 .3 (42)]

Testing new locomotives of the London, Midland & Scottish Railway (Great Britain) on the line.

(Génie Civil, 1st June 1948.)

Locomotives can be tested at a Testing Station or on the line by a dynamometer car with a train of wagons and one or more locomotives, called « regulators », the rôle of which is to maintain the convoy at a constant speed for a constant indicated power, (opening of regulator, position of cut-off and control of the exhaust).

at Vitry-sur-Seine, described in the *Génie Civil* of the 12th August, 1933.

In Great Britain, the Great Western Railway installed a Testing Station at Swindon and another testing station was under construction for the London Midland & Scottish and London North Eastern Railways when War was declared.

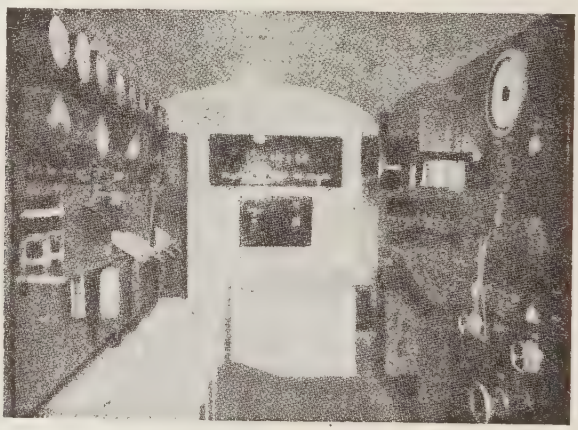


Fig. 1. — Interior view of braking unit.

Compartment containing thyratron rectifiers which control the exciting of the main generators, the master control and the apparatus of the auxiliary generating set and the auxiliary circuits of the braking units.

The Testing Station has the advantage of being able to carry out trials at a constant power (power at the wheel rim), the duration of the tests is not limited, and can furnish very precise information under exactly similar conditions.

The American Railways have various testing stations of this kind and the French National Railways have a Testing Station

Tests on the line, the first type employed, are less accurate and more difficult to execute owing to the difficulties of driving the regulating locomotive and the inevitable variations in certain factors from one test to another or even during the course of the same test; but are necessary in order that the locomotive may be studied completely. Comparing their results with those

of the testing station enables the value of the running resistance to be accurately assessed. (See *Génie Civil* of the 16th May, 1936, on this subject.)

To facilitate the carrying out of these trials and increase their accuracy, in 1936 the Research Department of the London, Midland & Scottish Railway (L. M. S. R.), proposed to replace the regulating steam locomotive by units equipped with electric generators acting as brakes. A constant speed can thus be automatically maintained by varying the exciting of the generators by means of regulators governed by a tachometer generator.

The L. M. S. R. staff designed and then had constructed three vehicles of this type for using with a new dynamometer car and a tender specially fitted for measuring the consumption of coal and water used during the tests. Owing to hostilities, this rolling stock could not be placed in service until the end of 1947 (« *Engineering* » of 3rd October, 1947, gives a detailed description), the braking units being converted for use as emergency generating stations during the war.

The braking units are carried on two four-wheel bogies, each coupled to a 375 HP generator, capable of absorbing up to 1 500 HP per unit. They only differ in method of suspending the generators and gear ratios which correspond to maximum speeds of 80, 144 and 192 km per hour (50, 90 and 120 m. p. h.). They can be used singly or together, according to the power and speeds required for the test.

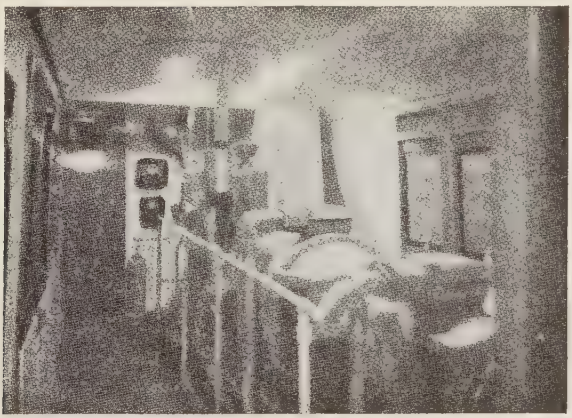


Fig. 2. — Interior view of a braking unit.

The auxiliary generating set, the 100 HP Diesel motor of which works the exciter, the generator which feeds the fan motors and that which charges the battery of accumulators. In front are the generators and, behind, the Diesel motor.

The generators of the braking unit, designed for a maximum speed of 80 km per hour, are simply nose-suspended. Those of the other two braking units are mounted on bogie frames and connected to the axles by means of Andrews-English Electric flexible axle drives which enable vertical movement to take place and, at the same time, permit a certain amount of lateral movement.

The generators in the same braking unit are excited by a single exciter, the voltage of which is regulated by means of the

tachometer generator of the dynamometer car in the following manner :

The fixed voltage chosen according to the speed at which the test is to be carried out is balanced against the voltage of the tachometer generator and the difference between these two voltages is amplified and transmitted to the circuit of the thyratron rectifiers which control the exciting of the main generator. The braking units are connected to the dynamometer car by a conduit which connects the thyratrons to the amplifier which is fitted in this car. The exciters can also be controlled by the experimental staff by means of master controls arranged in the dynamometer car (fig. 1).

The power generated by the generators is absorbed by banks of resistance grids, which are cooled by a current of air maintained by fans. The motors of these fans and those which cool the generators are fed by an auxiliary generating set (fig. 2), the 100 HP Diesel motor of which also works the exciter and generator connected in parallel with a battery of accumulators which supplies the lighting and heating when at a standstill.

The dynamometer car has two four-wheel bogies. It is equipped with an Amsler hydraulic dynamometer coupled to the leading drawhook. This dynamometer is connected to a recording table on which is recorded the speed and the work accomplished on a basis of either time or distance. The speed is measured by the voltage of the tachometer generator which governs the exciting of the generators. This tachometer generator and the totaliser of the distance run are driven by an additional unflanged wheel mounted on the leading bogie.

The master control of the generators of the braking units is arranged on a desk panel which also is equipped with meters indicating the loading of each of the braking units. Another desk panel is fitted with the apparatus which repeats and records the indications of the control apparatus (thermometers, gauges) of the locomotive.

The tender can hold three tons of previously weighed coal in sacks for the tests, and three tons of coal in bulk for the mileage run outside the tests; the consumption of water is measured by a water meter.

In order to study the influence of the direction and speed of wind resistance, a vane and anamometer is mounted on a light tubular frame fitted to the front of the locomotive (fig. 3), and the indications of these are transmitted electrically and recorded on the dynamometer table.

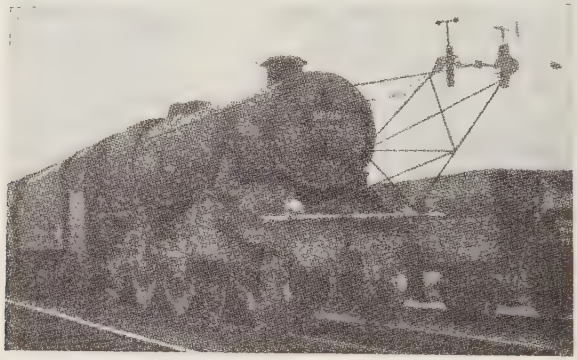


Fig. 3. — View of a locomotive under test.

The anamometer and vane fitted at the end of a light tubular frame should be noted.

[625 .231 (45)]

New rolling stock of the Italian State Railways.

(Trasporti Pubblici, February 1949.)

On the 13th February, 1949, the Italian Minister of Transport, accompanied by a party of journalists, took part in a special run on a test train consisting of the following :

electric locomotive E. 248;

heating wagon;

oscillograph coach for taking technical measurements;

saloon coach 78 on which the suspension was being tested;

Cz type coach with a new system of electric heating and fitted with improved seats;

Fig. 1. — Interior of E. T. R. series electric train recently constructed.

brake test unit fitted with quick action brake and anti-slipping device;

two 4-wheeled coaches of the Ci type with tubular body, central door and streamlined;

one C.I. type vehicle for secondary trains mounted on new articulated 2 wheel bogies;

Cz type coach with a new autonomous lighting system.

A brief description of these vehicles is given later.

The Vdlz brake test unit, which is specially equipped for enabling extensive trials to be carried out on automatic compressed air brakes used on the different European

railway systems, had been fitted experimentally with a series of three centrifugal interrupters for the quick action brake and three inertia interrupters for apparatus designed to prevent the slipping of wheels of vehicles.

The former, by closing an electric circuit under special control, could vary the maximum brake pressure at a certain speed to adapt it to that speed.

The latter come into action and release when the trains are composed solely of this new type.

There are 76 seats in the two compartments which are accessible from the platform (with two additional seats on the platform itself).

The large glazed windows 1 010 mm (3′ 4 5/32″) wide, open and are particularly easy to work owing to the use of a new type of balancer.

The coaches are equipped with electric

Fig. 2. — Exterior view of 3rd class C. I. coach.

a special pneumatic valve which tightens the brake shoes immediately slipping commences.

This prompt action prevents the grooving of wheels and eliminates the detrimental effect on the tyres.

The new third class 4-wheeled coaches for local services haves the following characteristics which differ from those of previous types :

a) they have a large central platform accessible from either side by means of two doors, which enable the quick embarking and disembarking of passengers;

b) the body is of welded tubular construction and in static tests has proved very rigid;

c) the body has an air-stream end shape which reduces air resistance, especially

lighting from accumulators and with steam heating. Provision has however been made for electric heating.

They are mounted on swivelling axles fitted with a special arrangement for guiding the axles which facilitates working round curves.

Designs are now being examined so that this type of suspension can be used on a normal bogie vehicle and good results have already been obtained.

The oscillograph coach is a test coach fitted with special apparatus for technical measurement, especially oscillographs.

During this test run, the variations of longitudinal, transverse and vertical acceleration of the body of saloon coach S 78, which immediately followed, were taken by

means of a portable « Hallade » apparatus placed in the coach.

These accelerations displace proportionately predetermined metallic masses, in the apparatus, which are suitably positioned in the three directions mentioned above.

The styluses, connected to these masses trace on paper, at a constant speed, their variation.

By this method, it is possible to compare the recorded accelerations of the vehicles whilst moving with a view to studying the best means of improving the running.

For the same purpose, and to complete the information, it is generally necessary to know (at the same time), what are the actual displacements between the various suspension details of the vehicle under observation. This is carried out by means of a Siemens oscillograph if the oscillations are not at too high frequency or a thermoionic oscillograph when the contrary is the case, which are installed in the specially fitted-up oscillograph coach.

During the test run, the transverse and vertical movements of the body of the C. I. coach were taken in relation to one of the axles of the vehicle whilst running.

These movements are transmitted by special calibrated wire into variations of the electric current and by means of the Siemens oscillograph are shown on photographic paper.

The special rubber suspension of coach Cz, which is of the most modern type of construction, consists of four nests of springs arranged between the axle and the body of the vehicle.

Three of these nests, in steel and rubber, carry the vertical suspension of the coach whilst the fourth, which is of rubber, prevents vibration at high frequency being passed from the bogie to the body of the coach.

In these modern bogies, the rubber springs, which consist of rings separated by metallic discs, are generally arranged in parallel with steel springs.

Fig. 3. — Interior of C. I. 3rd class coach.

Rubber suspension of coach Cz is a compromise in the division of loads between the rubber and steel springs.

This arrangement enables better running of the vehicle to be obtained, particularly with speeds higher than 100 km (62 miles) per hour.

This vehicle is fitted, for trial, with two steam heating couplings of a new standard type, conforming to recent international agreement.

This standard type, with which the whole pool of vehicles will soon be fitted, consists of three elements made entirely of metal, articulated by a spherical joint. Special rubber washers ensure the correct working of these under the most adverse conditions.

The vehicles are also fitted with self-contained lighting equipment which is an innovation for Italian coaches. Up to the present, the electric lighting of railway coaches was by moveable accumulator batteries, which had to be changed every time they became discharged so that they could be recharged at the appropriate fixed plant. This method of feeding, although it has the advantage of simplicity of installation on the coaches, is insufficient if good lighting is required.

The Italian State Railways, in accordance with their programme to adopt all improvements made possible by technical advance, are at the moment replacing this system by the more modern method of a dynamo attached to the axles which will bring them into line with the most modern railways of other countries.

The Italian State Railways Design Office has designed a new type of tension regulator for the dynamo which is cheaper than other types to-day on the market and reduces considerably the cost of each of the machines.

These are now being tested in service, the results of trials with the prototypes having been excellent.

Regarding the heating of vehicles during winter, the design of an electric heating system is now at the experimental stage.

With the present tendency to form trains of a large number of coaches, steam heating has proved insufficient as the heat does not extend to more than the 10 or 12 first vehicles, even if the couplings are in perfect condition.

In addition, in electrically driven trains, a special boiler mounted in an appropriate vehicle called a heating van, is necessary for steam heating.

With this system numerous personnel are needed not only for working the boilers but also at the depots and for maintaining these vans.

The inconvenience caused at marshalling yards by the shunting necessary to haul these heating vans, which are not self-propelled and must be hauled by locomotives to the front or rear of trains cannot be too strongly emphasised.

It is for this reason that electric heating is replacing steam heating, not only in order that trains may be uniformly heated but also to economise in personnel, particularly during the winter season when the need is generally greater. This is apart from working economies which may be realised.

This system has already been adopted by certain railways in other countries (Switzerland and France), and already a 100 Italian coaches, for international service, have been equipped so that they can take and use current on these railway systems.

International agreements lay down that they must be able to take current for heating at 3 000, 1 500 and 1 000 V. The electric heating of Italian trains commenced in 1948 when a small group of coaches was put into traffic. As these were not for international services they were only equipped for taking 3 000 V current which is that used for Italian locomotives.

It has been decided, gradually and progressively, to alter all coaches for internal traffic in Italy, in accordance with this system.

Experience was gained, during the 1948-1949 winter, which was based on results

of trials made the previous year. 40 trains working on the D.C. electrified system have already been fitted with electric heating at 3 000 V.

The radiators are placed under the seats and in each compartment is a regulator under passengers control. It was hoped that experience would prove definitely the types and details of construction required.

During 1950, electric heating will be extended by putting into service a number of coaches which, if all goes according to plan, should reach about a thousand.

A considerable number of electric locomotives must be put in order to haul the trains.

The heating system of Italian trains can only be gradually altered; new rolling stock is still fitted with both systems of heating, electric and steam.

The trial during the 1948-1949 winter met with the general approval of passengers, who gave the new system a very warm welcome.

Electric heating is a real step forward towards the general increase in comfort, which the State Railways have made their aim throughout their administration.

[621 .438 (73)]

The experimental coal-burning gas turbine,

by John I. Yellott,

Director of Research, Locomotive Development Committee †

(From the Railway Age, April 15, 1950.)

The most pressing need for a coal-burning gas-turbine power plant is in the locomotive field, where bituminous coal continues to be the cheapest fuel. Since 1945, coal's cost per million B.t.u. has risen from 12 cents to approximately 18 cents, while Diesel oil has climbed from 50 cents to 69 cents per million B.t.u. The cost of residual oil has fluctuated widely, and for the western roads, but not the eastern, it has frequently been cheaper than coal. The cost of the fuel required to pull a train depends as much upon the thermal efficiency of the locomotive as upon the price of fuel. Coal was formerly cheap enough to compensate for the low efficiency of the steam locomotive, and even today a few roads can show that steam is still their most economical motive power. In most cases, however, the highly efficient Diesel-electric locomotive shows large savings over steam equipment. The gas turbine, because of its ability to use low-cost fuels with good efficiency, is a formidable competitor of the Diesel-electric locomotive for road service Except at idling, the coal-burning gas-turbine locomotive is expected to cost much less to operate than any of its competitors.

In road service where the average load is 60 to 75 per cent of full power, the coal-burning turbine should save $ 12 to $ 15 per hour over the Diesel's fuel cost. An annual fuel saving in the order of $ 50 000 per locomotive can be expected at present fuel prices. This is the economic justification for the eastern railroads' efforts to develop the coal-burning gas turbine. More broadly, the vastly greater world-wide coal reserves, as compared with oil, give long-range significance to the program of the Locomotive Development Committee of Bituminous Coal Research, Inc.

Small-scale component development.

The coal-burning gas-turbine plant is the result of four years of work, during which all of the necessary components were first tested on a small scale at atmospheric pressure. Simultaneous attacks were made upon the problems of coal handling, combustion, and ash removal.

[The author here described the various research projects, the results of which have led to the present status of the locomotive equipment. These included the study of preparation, pressurizing, pulverizing and combustion on a small scale at Johns Hopkins University; a study of combustion at atmospheric and elevated pressures at Battelle Memorial Institute (1); a study

(1) « Experimental Combustion of Pulverized Coal at Atmospheric and Elevated Pressures », by H. R. Hazard and F. D. Buckley, Transactions of the American Society of Mechanical Engineers, August, 1948.

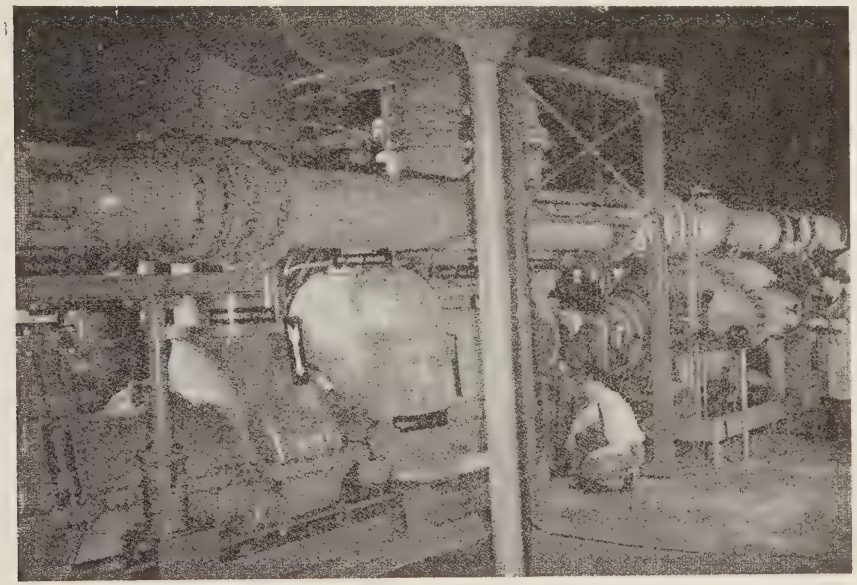
An abstract of a paper presented before the Midwest Power Conference at Chicago on April 7.

† The Locomotive Development Committee is composed of the chief executive officers of the Baltimore and Ohio; Chesapeake and Ohio; Illinois Central; Louisville and Nashville; New York Central; Norfolk and Western; Pennsylvania; Virginian; New York; Chicago and St. Louis; the M. A. Han a Company; Island Creek Coal Company; Pocahontas Fuel Company; Pittsburgh Consolidation Coal Company; and the Sinclair Coal Company. Roy B. White, president of the B. & O., has been chairman of the committee since its formation in 1944.

of the fly-ash problem (1), methods of improving performance of the coal atomizer, partial gasification of coal, and pressurizing finely crushed coal all at the Institute of Gas Technology at Chicago. The effect of sulphur in coal on stainless steel was investigated at Purdue University (no measurable effect was found on the gas-turbine conditions up to 1 800 deg. F.). Southern Research Institute developed an air-balanced device for determining feed rates from a pulverized coal tank. — Editor.]

By mid-1946 a pilot plant had been installed at the Dunkirk, N. Y., plant of the Alco Products Division of American Locomotive Company, where coal could be burned under pressures as high as 60 lb. per sq. in. gage at rates up to 1 000 lb. per hour (1). A larger version of the Johns Hopkins coal system was constructed, using a standard stoker piston coal pump to pressurize the coal.

Feeding of crushed coal from the pressurized storage tank was accomplished by the use of a variable-speed screw. A coal atomizer was used for pulverization. Shop air at rates up to 1 000 lb. per min. was available to burn the coal, cool the combustor, and chill the ash. A battery of small centrifugal separators removed most of the fly ash before the heated air was released through a pressure-reducing valve and allowed to pass through a turbosupercharger to determine the effect of the remaining ash upon high-speed turbine blades.



The Allis-Chalmers Houdry process coal-burning gas-turbine installation at the Dunkirk, N. Y. plant of the American Locomotive Company. F. D. Buckley (standing, center) is the manager of this installation.

(1) « Studies on Fly-Ash Erosion » Fisher and Davis, *Mechanical Engineering*, June, 1949, page 481.

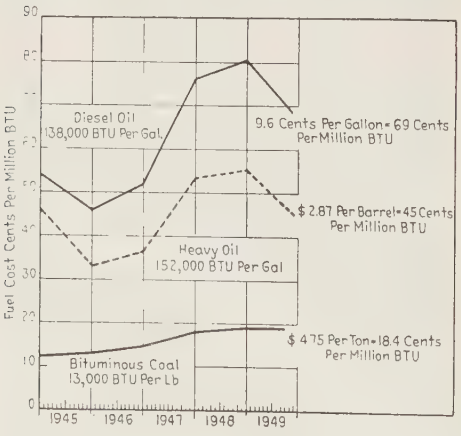
(1) The « Coal-Burning Gas-Turbine Locomotive », by J. I. Yellott, C. F. Kottcamp and P. R. Broadley, 1947 annual meeting. American Society of Mechanical Engineers. Abstracted in January 31, 1948, *Railway Age* p. 254.

Operation of the pilot plant disclosed a number of major problems which had not been discovered in small-scale operation at atmospheric pressure. Most serious was the fact that, with 90 per cent combustion efficiency, the best then obtainable with cold-wall combustors, the carbon remaining in the ash burned vigorously in the fly-ash separators. In a ceramic-wall slagging combustor, in which efficiency of combustion consistently approached 98 per cent, about half of the ash appeared as slag in lumps of moderate size. The remaining fly wash was sufficiently low in carbon content to be harmless to the fly-ash separators.

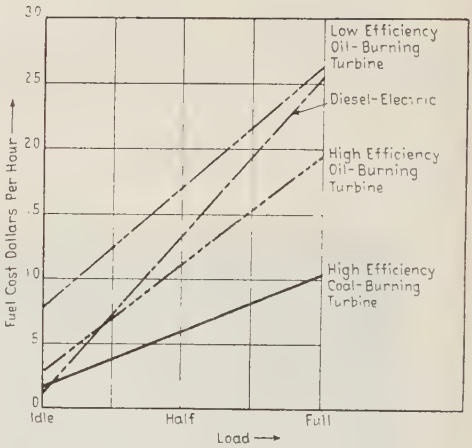
Work is continuing on an atmospheric-pressure, full-scale, horizontal ceramic combustor. For low-ash-fusion and low-volatile coals the ceramic tube shows considerable promise. The all-metal combustor will be used, however, in the first tests of the actual locomotive power plant.

Full-scale tests of components.

Small-scale, low-pressure tests showed the necessity of working with full-scale equipment under actual gas-turbine conditions. This phase of the work was undertaken in conjunction with the Turbodyne Cor-



Average fuel prices reported to I. C. C. by three eastern railroads showing variations since 1945.



Variations of fuel cost per hour with the load — 4 500 HP gas-turbine locomotive.

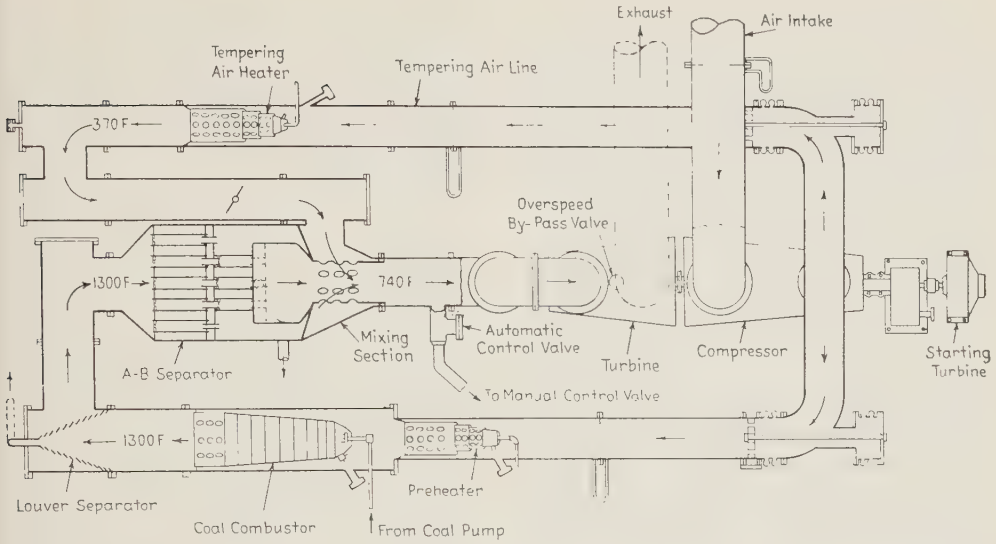
poration, a subsidiary of Northrop Aircraft, at the Kaiser steel mill, Fontana, Cal.

During the summer of 1947 coal-handling equipment of locomotive size was installed at Fontana. Coal from a locomotive stoker was fed through a hammer mill and a slide-valve lock hopper into a large, high-pressure tank. The system was first operated under pressure in December, 1947, and in the months which followed it became evident that film-cooled metal combustors could be used with acceptable range, efficiency and life.

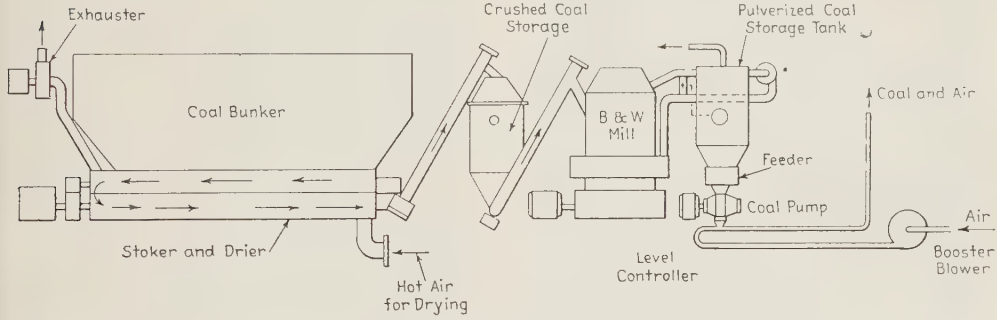
Feeding from a pressurized tank appeared to be impractical on a large scale, and, consequently, an attack was made on the problem of continuously pressurizing finely crushed coal. A rotary pump was developed in which extremely close clearances were maintained by a refined mechanical design. Such a pump proved practical for transferring coal from an atmospheric pressure source into a line at pressures up to 140 lb. per sq. in.

Two-stage ash removal.

Because of the extremely wide size range of the ash-particles, it was found necessary to use a two-stage ash-removal system. A louver separator was used as the first stage



Arrangement of the combustion and ash-separation equipment of the Dunkirk Houdry gas-turbine installation.



The coal-supply system which will be installed on the Locomotive Development Committee's gas-turbine locomotive.

to concentrate the large particles of ash into a small quantity of flowing air, which was then blown down to atmospheric pressure through an aspirating nozzle. The quenching of the incandescent ash particles by the aspirated cold air prevented the burning of the separator on this blow-down line.

As a second stage of fly-ash removal, a battery of small cylindrical separator tubes of the straight-through type was employed. These tubes caused most of the dust to be removed by imparting a vigorous spin to the air and dust and drawing off the concentrated solid particles in a small secondary stream of air. Again, the continuous blow-down method was used to dispose of this dust. Extensive tests of the ash removal system indicated that very few particles larger than 20 microns in diameter were getting through the system.

The Houdry turbine at Dunkirk.

The United States Bureau of Mines made available to the committee a Houdry-process gas-turbine plant, originally destined for a Russian oil refinery. The air compressor of the Houdry unit takes air from the atmosphere through a metering section and a silencer, The discharge of the compressor is divided into two lines, one of which contains the coal combustion system and the fly-ash separators. The other line contains an oil-burning system, so that the unit may be started on oil and then transferred to coal. One of the illustrations is a plan of the arrangement.

To simulate the performance of one of the twin combustors which will be used with the 4 200 HP locomotive turbine, the air flow from the compressor can be divided so that approximately 93 000 lb. per hour will pass through the coal side, while the remaining 113 000 lb. passes through the oil side. An oil-fired air preheater is also installed on the coal side, to provide the temperature rise which will be encountered in the regenerator of the locomotive gas turbine. The coal-burning and ash-removal equipment is made entirely of stainless steel, so that it can be safely operated at 1 300 deg. F.

The coal-burning combustor currently in use at Dunkirk consists of telescoping cylindrical sections of stainless steel, 1/8 in. thick, supported by external girders. A riveted construction was originally employed, but was replaced because of the building up of ash deposits in the wake of each rivet. Combustor cooling is accomplished by admission of air at slots between adjoining rings. Mixing of excess air with the products of combustion takes place through large holes in the last 30 in. of combustor length.

Admission of coal to film-cooled combustors has received much study, and the burner currently in use is a Dunkirk modification of a multi-jet device originally used at Battelle Institute. The combustion efficiency obtained with this arrangement has consistently exceeded 95 per cent. Coal has been burned in this combustor at rates up to 1 800 lb. per hour. After a continuous test of 32 hours, the combustor was found to be relatively clean and completely undistorted. Development is going forward to improve this type of combustor, so the gas turbine can be operated on coal without need for an oil pilot flame.

The louver separator which forms the first stage of the ash-removal equipment, also built by Turbodyne, has withstood several hundred hours of operation without any visible deterioration. It removes approximately 50 per cent of the solids contained in the combustion products, and also effectively eliminates stratification in the heated air leaving the combustor.

Final removal of the fly ash is accomplished by a battery of 18 American Blower Type ST separators. Approximately 90 per cent of the 20 000 cu. ft. per min. discharge from the combustor passes directly through the tubes, transferring most of the remaining dust into approximately 10 per cent of the air stream which passes through the secondary tubes. This dust is concentrated again into approximately one per cent of the original air stream, which is then blown down through a small nozzle. The remaining nine per cent, containing fine dust not removed in the secondary collection system, can be readmitted to the main stream as it passes toward the turbine.

Mixing relatively cool air from the oil-heater side with the 1 300 deg. F. flow from the coal-burning equipment is accomplished by a mixing zone which is virtually the same as the cooling section at the end of the combuster.

At a firing rate of 1 800 lb. of coal per hour, the heat release is approximately 750 000 B.t.u. per hour per cu. ft., or 6 000 000 B.t.u. per hour per sq. ft. of cross-section area. Under these conditions, the combustor runs relatively cool and clean. There has been very little slagging in the combustor, and virtually all of the ash appears as a fine dry powder suspended in the combustion products.

Coal preparation equipment.

The coal for the Houdry gas-turbine plant is provided, first, by an Iron Fireman

stoker which supplies coal in minus 2-in. lumps to a Whiting high-speed impact mill which includes a fan and a classifer. The fine coal, 97 per cent — 100 mesh, flows with the coveying air upward through an 8-in. pipe into a coal separator in the top of the pulverized coal-storage tank. This separator is a combination of two American Blower Type ST 361 tubes and a louver. The cleaned air is returned to the pulverizer. The vented air, always required in a closed circuit system, is the secondary flow from the American Blower tubes. Make-up air is provided through an opening at the inlet of the pulverizer. The level of coal in the tank is controlled by a single Fuller rotary level indicator located just below the coal separator. This controller starts and stops the motor on the pulverizer feeder. The stoker operates in response to a level control on a small hopper from which the pulverizer feeder takes its supply.

Feeding of the coal is accomplished by a variable-speed drum feeder. The pulverized coal in the storage tank is highly aerated, and its bulk density is as low as 20 lb. per cu. ft. This coal is fluidized to such an extent that it will flow very readily through even the smallest crevices. Some difficulty has been encountered from leaks in the feeder, and this problem is still undergoing vigorous study.

The continuous pressurizing of the coal at whatever rate may be established by the feeder is accomplished by the rotary coal pump. It appears that the blow-through feature of the pump developed by the Turbodyne Corporation at Fontana is essential. The pulverized coal is carried from the bottom of the pump to the combustor by compressed air flowing in a 1 1/4 in. line.

Future work with the Houdry unit.

The Houdry unit was installed for the dual purpose of demonstrating that coal can be successfully used as fuel for a full-scale gas turbine and as a research installation to permit development of improved coal-handling, combustion, and fly-ash-removal equipment. At present it is being operated as many hours as possible each week to determine the effect of the unremoved fine dust upon the blades of the turbine. After the first 150 hours of operation, inspection of the last row of blades, made by entering the turbine through the exhaust duct, indicated no damage whatsoever. A very thin layer of fine dust adheres to the blades, but there is no evidence of any impairment of the turbine performance. The Houdry turbine is operating at a temperature much lower than a power-generating gas-turbine, and it will not be safe to conclude that the problems of ash removal are solved satisfactorily until a full-scale, full-temperature gas turbine has been operated on pulverized coal for thousands of hours.

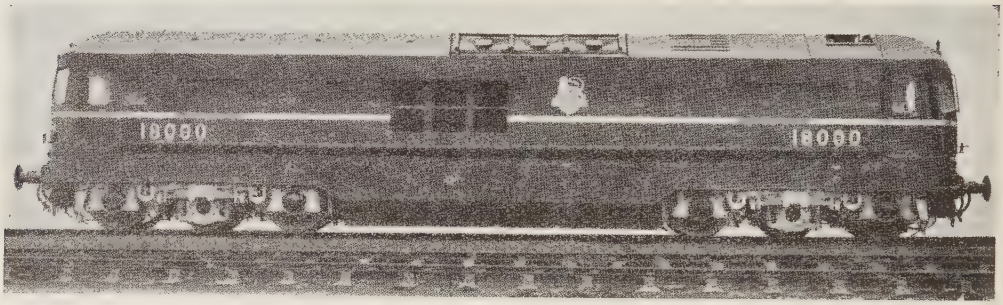
It is the intention of the Locomotive Development Committee to push the project to completion as rapidly as possible. The first experimental locomotive will be composed of two units, with the power plant mounted on one and the coal preparation equipment, shown in one of the illustrations, on the other. The Allis-Chalmers 4 200 HP gas-turbine power plant has undergone preliminary tests. It will be moved to Dunkirk soon for extensive stationary tests in an installation which will duplicate in every important particular the arrangement in the locomotive. If these tests are satisfactory, the power plant will be installed in a locomotive and extensive road test undertaken.

[621 .438 (42)]

British Railways first gas-turbine locomotive,

Brown-Boveri 2 500 HP locomotive for the Western Region incorporating a single-stage open-cycle turbine with heat exchanger.

(*The Railway Gazette, May 5, 1950.*)



The Brown-Boveri gas-turbine locomotive, built for the former Great Western Railway Company and recently delivered to the Western Region, British Railways, is about to go into service. The locomotive arrived in this country during the first week-end of February. Since then it has made a number of trial runs and has been subject to the usual tests.

The locomotive is double ended; two identical cabs giving unobstructed lookout are provided. The power unit, consisting of gas turbine, compressor, heat exchanger, combustion chamber, and geared generator assembled on an auxiliary frame, takes up the larger part of the machine room, which is partially sub-divided by the air intakes to the compressor.

At the combustion chamber end is the auxiliary diesel-generator set, the train-heating boiler, and one of the traction motor fans. The other fan is placed at the main generator end, together with the mechanically-driven and the motor-driven exhauster-compressor sets for the brakes.

Fuel oil, lubricating oil, and water are carried partially in the roof and partially in the middle portion of the main frame.

Principal dimensions.

The main technical data of the locomotive are as follow:

Gauge	4 ft. 8 1/2 in.
Length over buffers	63 ft. 0 in.
Max. height from rails	13 ft. 4 in.
Diameter of driving wheels	48 1/2 in.
Diameter of carrying wheels	38 in.
Continuous rating of gas turbine unit	2 500 HP
Tractive effort at wheels :	
During starting	31 500 lb. up to abt. 21 m.p.h.
Continuously	12 400 lb. at 64 m.p.h.
	8 400 lb. at 90 m.p.h.
Maximum speed	90 p.m.h.
Number of driving axles and traction motors	4
Weight of mechanical part	118 000 lb.
» thermal part	72 000 lb.
» electrical part	53 000 lb.
Weight of stores (fuel, water, sand, etc.)	17 000 lb.
Weight per axle	43 000 lb.
Adhesive weight	174 000 lb.
Fuel	Heavy fuel oil

The mechanical part supplied by the Swiss Locomotive & Machine Works consists essentially of two identical three-axle bogies, the main frame, and the coach body supported thereon.

The frame and transverse beams of the bogie are of tubular section, made of high-grade steel and welded throughout, as shown on page 98. Care has been taken to avoid excessive concentration of stress. The bogie frame rests on the axle boxes through helical springs.

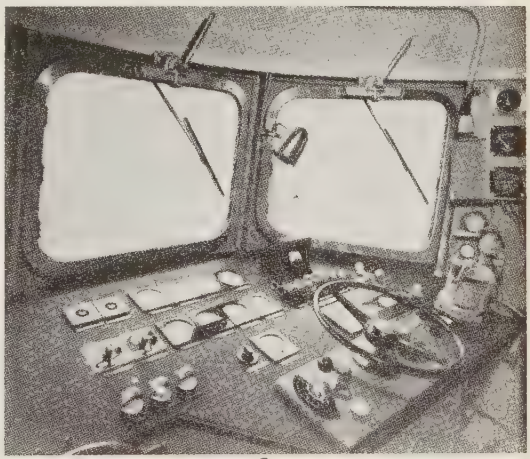
The axle boxes have SKF roller bearings and are guided by two vertical cylindrical pins. These pins are case-hardened and ground. Screwed inside them are rods for holding the boxes in a downward position and for fixing the friction dampers. To damp out vertical oscillations a dry friction damping device is provided underneath, the amount of damping of which can be adjusted.

The two outer axles on each bogie are each driven by an electric motor through gears; the centre axles on each bogie are carrying axles. The driving axles are held sideways on the driving side only, the outside race of the roller bearing being held there between the two covers of the bearing. On the other side the roller bearing is provided with a certain amount of side play.

New bogie design.

The arrangement for the support of the body and the transmission of the tractive and braking forces are shown in the sectional drawing, which gives a cross-sectional view of this new design of 3-axle bogie with lateral play of the middle axle as developed by the Swiss Locomotive & Machine Works, Winterthur.

As will be seen from the same drawing, the body rests at each side on the two corresponding springs 12 and 13 through the supports 17 and 18 lodged in buckets forming one piece with the buckle of the springs. These buckles and consequently their springs 12 and 13 are made to move integrally with the main frame by the links 16. The ends of the springs forming one pair are connected by equalisers 11 which transmit their load to the frame through the inclined swing links 14. They are also joined to each other by means of the floating beams 10 which, for sideways movements, make them move integrally with the body by means of the coupling links 9 and the cross-head 5. All articulations between the body and the bogies for controlling lateral and longitudinal motions, are fitted with silentblocs. To allow of the side play of the middle axle, the axle box 21 is separated from the guides 24 and the vertical load is transmitted from the box to the guides by means of the floating beams 22 and 23 which also exert on the axle at the same time a certain centring force.



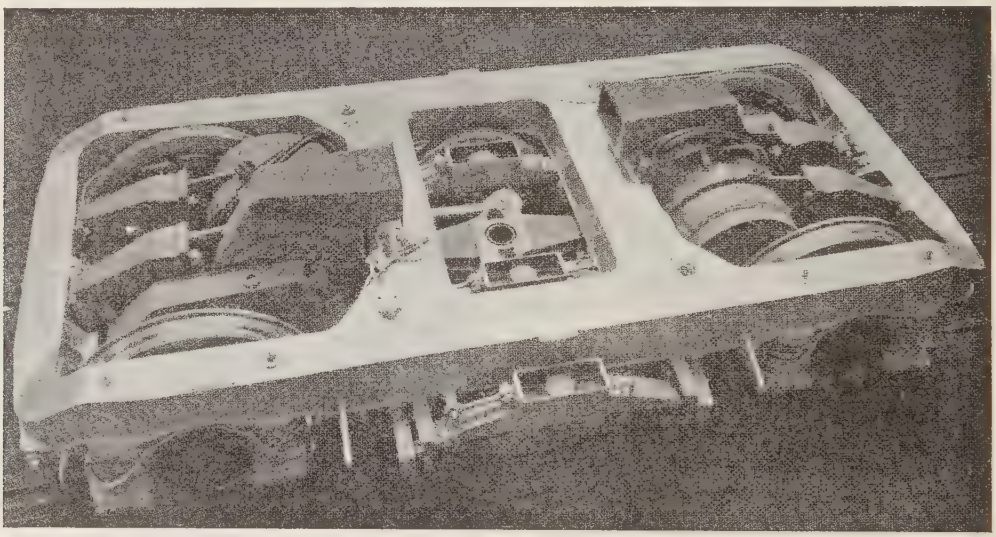
View of driver's cabin showing the controls.

The driving motors transmit their torque to the wheels through the Brown-Boveri individual axle drive with quill stump and spring coupling. With this drive a considerable reduction is achieved in the total unsprung weight in contradistinction to nose-suspended motors, be-

cause it allows the motor and gear to be rigidly fixed to the bogie frame.

The unsprung weight is thus reduced to a minimum, comprising only the wheels, axle, axle boxes, and the carrier disc. In addition, the spring drive gives the possibility of utilising very high-speed driving motors of big output and light weight.

Transmission of the torque to the driving axle is on one side only; see illustration on page 99. The working principle of the Brown-Boveri spring drive can be seen from diagrammatic views of the axle drive illustrated on pages 103 and 104. A quill stump 1, secured to the housing of the motor, surrounds the driving axle 7 with sufficient play to leave complete freedom to the relative movements of the driving axle and the underframe. The gear wheel 3, driven by the motor pinion 2, is carried by two spherical roller bearings mounted on the quill stump. The transmission of the torque from the gear wheel to the driving axle is flexible through 8 coil springs 4, which are built into the spring cups. The lips 5 on either side of the rim of the gear wheel form the sides of the spring cups. The two ends of each coupling spring are formed by caps which are guided in the cups. A carrier disc 8 pressed on to the axle, and the 8 rugged spider arms of which press on the spring caps, forms the coupling between the big gear wheel and the driving axle which can move vertically. The coupling springs are compressed when relative movement occurs between the carrier arms and the gear wheel. Stressing of the springs due to centrifugal force can be disregarded because the springs press on their whole length against the outer wall of the spring cup. The whole gear with springs and sliding surfaces of the spring caps is protected from dust and dirt by a closely-fitting gear case 6, which also allows of effective lubrication of the teeth and of all moving parts. The lubricant (oil) is taken up by the gear wheel and maintained in constant circulation over all vulnerable parts.



Showing the bogie frame of tubular construction, centre pivot, and side bearers.

The underframe of the locomotive is carried on the bogie bolsters as previously explained. The underframe girder is welded throughout and built up of constructional steel sheet. The cross stretchers and stiffeners are secured by rivets. Built into the underframe between the bogies are the tanks for water, heavy fuel, and lubricating oil. Fixed to this section of the underframe are also compartments for the storage battery and pump sets.

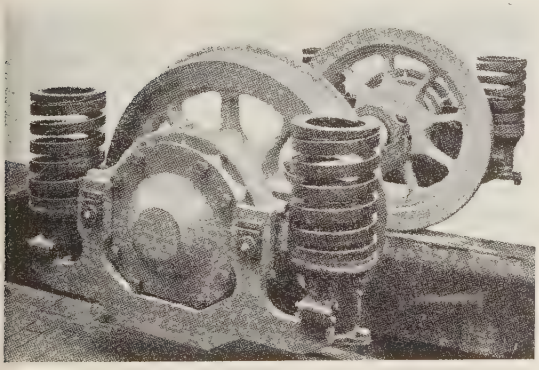
The auxiliary frame carrying the entire thermal power unit is supported in the main frame on a three-point suspension. The arrangement prevents the elastic distortions of the locomotive from being transmitted to the auxiliary frame and thus to the thermal unit, and secures a very steady riding of the locomotive.

The sections of the locomotive body, that is, the side panels as well as the roof sections, are bolted to ribs (continuous or in sections where necessary), whereby sufficient elasticity of the whole structure is secured and the body as a whole can follow the deflection of the locomotive main frame, which amounts to approximately 3/8 in., without distortion of the individual parts.

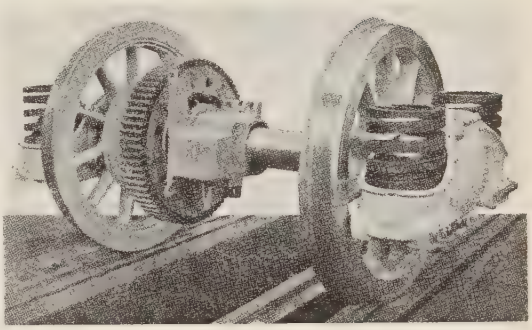
Coach body.

The coach body is sub-divided by tightly-fitting partition walls into two closed-off driver's cabs and the engine room. Each cab has two side doors and a third one leading to the machine room, which is provided with two side gangways. The two driver's compartments are riveted to the main frame, whereas the middle part of the body is bolted for its whole length to the floor plating of the frame. With the exception of those of the train-heating boiler compartment, all side panels can be removed from the body frame on the outside so that the greatest possible accessibility to the power unit and apparatus is provided. The central portion of the side walls is occupied by the oil cooler assembly consisting of three coolers on each side. As regards the frame of the body itself, the main body ribs between the compartment for the steam-heating boiler and that for electrical apparatus can also be removed so that the complete power unit, including generator and combustion chamber, can be placed in position from above.

The roof sections over the train-heating boiler and over the power unit are removable to facilitate the erection of the larger parts of the equipment. The roof above the combustion chamber is provided with ventilation louvres, and the part over the heat exchanger with longitudinal baffled slots which allow the exhaust gases to escape without permitting rainwater to



Floating beams and helical springs.



Gearwheel mounted on axle and quill stump for fixing to motor housing.

enter. The roof portions above the auxiliary diesel and the rear cab accommodate service tanks for water and light fuel oil.

The locomotive has a compressed-air brake system for the locomotive and vacuum brake equipment for the train. This arrangement was necessary because the restricted overall dimensions to which the locomotive had to be built precluded the use of vacuum equipment on the locomotive. The two systems are so combined that by the operation of one control handle by the driver the brakes are simultaneously and proportionately applied both on the locomotive and on the train. In addition, however, the driver has at his disposal a second brake handle which acts only on the locomotive pressure brakes, which affords particularly smooth and exact braking of the locomotive when engaged in shunting or running light engine.

The compressed air for the engine brakes and pneumatically-operated apparatus and the vacuum for the train brakes are generated by two reciprocating exhauster-compressor sets; one is electrically-driven, and the other belt-driven from an extension of the generator shaft.

Brake-rod arrangement.

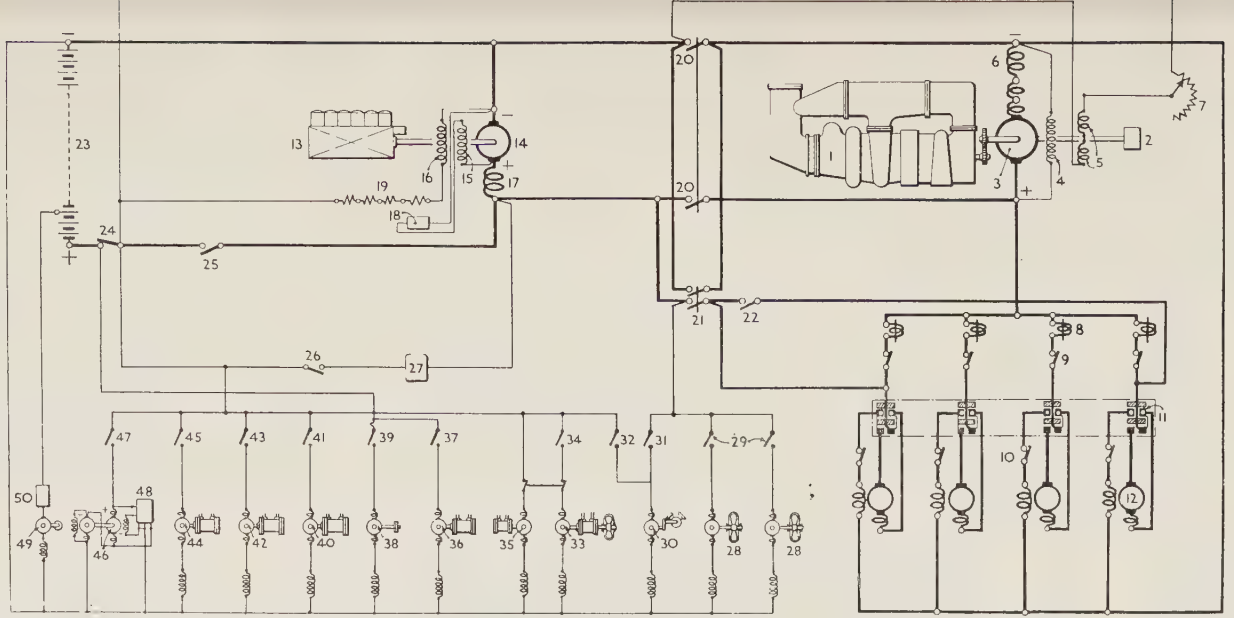
The brake-rod arrangement of each bogie is divided into two independent sets, each actuated by a separate brake cylinder which allows of considerable simplification and unification of the different parts. The brake cylinders are located underneath the outside cross stretchers of the bogie frame. The hand brake is each cab acts on the neighbouring brake set of the corresponding bogie. Electrically-controlled pneumatic sanders are provided for the driving wheels.

The gas-turbine power unit.

A single-stage open-cycle gas turbine with heat exchanger is used for the power unit, a cross-section drawing of which is shown. The air is aspirated by the compressor, compressed, passed through the heat exchanger where it is preheated, and delivered to the combustion chamber. There, one part of the air is used for the combustion of the fuel oil injected under pressure, whilst the remaining and by far larger portion of air serves for cooling the side walls of the combustion chamber and for reducing the gas temperature at turbine inlet to the value determined by the heat-resisting qualities of the blade material and the long service life demanded for such a plant. The hot gases expanding in the gas turbine produce mechanical work, part of which is used to drive the compressor, and the rest, forming the actual useful output, transmitted to the main generator through a reduction gear. Before escaping through the roof to atmosphere the turbine exhaust gases pass through the heat exchanger, giving up part of their heat to the compressed air on its way to the combustion chamber, which brings about a corresponding reduction in fuel consumption.

The air is aspirated through openings symmetrically placed in each side wall of the locomotive and connected to the air intakes of the compressor by two enclosed ducts. This has been done to prevent the combustion air becoming mixed with oil vapours or preheated in the machine room. The casing of the multi-stage axial flow compressor is of cast steel and rests on the auxiliary frame, which also carries the gas turbine and the generator with gear. The compressor blades are of special steel. The air outlet pipe from the compressor is provided with several expansion joints to deal with the different expansions of the gas-turbine set and the air heater. The latter consists of a great number of tubes expanded at both ends into tube plates.

In contradistinction to plants derived from aircraft design there is only one combustion chamber, which is lined with removable sections of special steel. The fuel is delivered by a separate pump set and sprayed into the combustion chamber



1. Gas turbine.
2. Speed governor of gas turbine.
3. Main generator.
4. Shunt excitation winding of main generator.
5. Separate excitation winding of main generator.
6. Counter compound winding of main generator.
7. Resistance in separate excitation circuit of main generator actuated by servo-field regulator for keeping power constant in normal running.
8. Overload relays.
9. Traction motor contactors.
10. Traction motor isolating switches.
11. Reversing switch.
12. Traction motors.
13. Auxiliary diesel engine.
14. Auxiliary generator.
15. Shunt excitation winding of auxiliary generator.
16. Separate excitation winding of auxiliary generator.
17. Counter compound winding of auxiliary generator.
18. Voltage regulator for auxiliary generator.
19. Resistances in separate excitation circuit of auxiliary generator for controlling speed of locomotive when running as light engine under power of diesel engine.
20. Starting contactor for gas turbine.
21 & 22. Contactors for locomotive running as light engine under power of diesel engine.
23. Starter battery for diesel engine.
24. Main battery switch.
25. Starting contactor for diesel engine.
26. Battery charging contactor.
27. Battery charging relay.
28. Traction motor blower motors.
29. Contactors for traction motor blower motors.
30. Motor driving auxiliary exhauster-compressor set for brakes.
31. Contactor for auxiliary exhauster-compressor set running on diesel engine.
32. Contactor for auxiliary exhauster-compressor set running on battery.
33. Motor driving draught fan and fuel pump of train heating plant.
34. Contactor for 33.
35. Motor of boiler feed pump of train heating plant.
36. Motor of pump for circulating bearing cooling oil (while turbine is cooling down).
37. Contactor for cooling oil pump motor.
38. Motor automatically « barring » round turbine at intervals (while turbine is cooling down).
39. Contactor for motor of automatic barring gear.
40. Motor driving pump for heavy fuel-oil.
41. Contactor for heavy fuel-oil pump motor.
42. Motor driving pump for light fuel-oil.
43. Contactor for light fuel-oil pump motor.
44. Motor driving pump for pressure oil of control system.
45. Contactor for control oil pump motor.
46. Voltage converter set.
47. Contactor for voltage converter set.
48. Voltage regulator for voltage converter set.
49. Motor of ignition rod control.
50. Ignition rod control apparatus.

Simplified diagram of main electrical circuits.

by a single centrally-located injection nozzle of special design. The combustion air is admitted to the spray through swirl vanes. The set is started up on light fuel (diesel) oil, and when thoroughly warmed through is changed over to heavy fuel-oil for normal service.

To obtain good atomisation in the burner nozzle, the high-viscosity heavy-fuel oil used is preheated in a system of tubes placed in the stream of the exhaust gases. The flame in the combustion chamber is ignited at starting of the set by an electrically heated ignition element. As the combustion gases pass down the combustion chamber they are gradually mixed with the excess air until a uniform temperature is reached at the gas-turbine inlet.

The inlet casing of the multi-stage reaction-type gas turbine is of special cast steel, and the blades of a special heat resisting alloy. Stainless steel has been used for the slotted roof portion over the heat exchanger through which the exhaust gases leave the locomotive. To reduce radiation losses all parts of the power unit are lagged and covered with aluminium sheeting.

The gas turbine and the air compressor are each supported by two journal bearings; the compressor end bearing is a combined journal and thrust bearing to take up any residual axial forces of the set. The generator is driven from the compressor shaft through a single helical reduction gear equipped with a special collar to take up the axial thrust due to the inclination of the teeth. Pinion and compressor shaft are connected by a toothed type coupling. All bearings of the thermal-electric unit are lubricated by oil under pressure supplied from a direct-driven gear type oil pump located in the main gear case. Fin type oil coolers are mounted in the air intake openings in the side walls of the locomotive.

Power unit data.

The following are the main technical data of the gas-turbine power unit at full load.

Compressor delivery pressure	36 lb./sq. in. g'
Gas turbine inlet temperature	1 100° F.
Exhaust gas temperature	Abt. 480° F.
Gas turbine and compressor speed	5 800 r.p.m.
Gear ratio	6·6 : 1
Generator speed	875 r.p.m.
Input at generator coupling	2 500 HP
Overall thermal efficiency	16·9 per cent.
Corresponding fuel consumption	0·87 lb./h.p.h.
Overall thermal efficiency at 80 per cent. load	17·5 per cent.

Characteristic data of the heavy fuel oil used are :

Specific gravity	0·95 at 60° F.
Viscosity	950 sec. Redwood 1 at 100° F.
Net calorific value	17 400 B.T.U./lb.
Ash content	Abt. 0·05 per cent. (0·1 per cent. max.)

A simplified diagram of the main electrical circuits is shown on page 101. The main generator supplies the four D.C. traction motors, which are continuously connected in parallel, through the motor isolating switches and the reversing switch which determines the direction of running of the locomotive. The motors are protected by overload relays in the main motor leads acting on the isolating contactor of the respective motor.

Electrical equipment.

The electrical equipment comprises the main generator, the traction motors, the auxiliaries, and control apparatus.

The main generator. — To obtain the strongly drooping characteristic essential for traction purposes the generator is equipped with three inter-acting excitation windings, namely : a counter-compound winding, a shunt winding, and a separately excited winding. The latter is fed from the auxiliary generator.

The rotor carrying the electrically and magnetically active part of the armature

is a hollow steel casting. At the driving end the armature shaft is constructed so as to form a flange which is bolted rigidly to the flange of the reduction gear so that at this end the armature is supported by the bearing of the reduction gear. The generator itself has only one bearing at the commutator end, and is of the journal type lubricated by oil under pressure. The armature lamination assembly is pressed on to ribs on the hollow rotor.

The commutator is bolted to the hollow armature shaft. The brush holders are carried by easily removable brush arms of a similar construction to those of the driving motors. The brush gear can be rotated.

The generator is self-ventilated. The fan is placed on the commutator side. The cooling air is drawn in on the driving side and expelled underneath after passing over the bearing.

The main generator is a multi-polar machine with commutating pole and compensating windings.

The ratings of the main generator are as follow :

Continuous rating ...	2 340 A. at approx. 675 V
One-hour rating	2 640 A. at approx. 760 V
Max. working speed.	875 r.p.m.

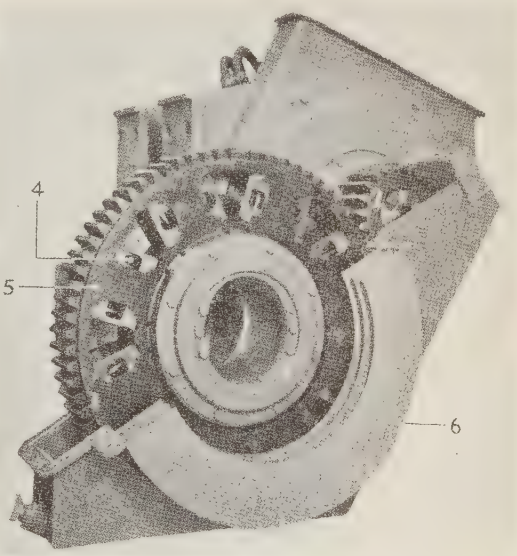
The traction motors are entirely spring-borne (*i.e.,* free with respect to axles) and rigidly fixed to the bogie frame. The motor torque is transmitted to the driving wheels by means of the Brown-Boveri spring drive.

The motors are of the series wound type and have forced ventilation. Their ratings are as follow :

Continuous rating...	397 kW, 720 V, 585 A, 1 550 r.p.m.
One-hour rating.....	394 kW, 636 V, 660 A, 1 290 r.p.m.
Gear ratio.....	21 : 73 = 1 : 348.

The motors have a cast-steel frame containing six main poles and six auxiliary poles. The armature shaft runs in roller bearings. The six brush carriers, each carrying two brushes, are supported by a ring which can be turned to allow of access to the brushes by the opening underneath the motor.

The auxiliaries. — The locomotive is equipped with an auxiliary direct current generator driven by a six-cylinder four-stroke Saurer diesel engine. In addition



1. Quill stump secured to motor housing.
2. Motor pinion.
3. Big gearwheel.
4. Transmission spring.
5. Gearwheel flange lip.
6. Gear case.

Traction motor with Brown-Boveri individual axle drive.

to the separate excitation current for the main generator the auxiliary generator provides the power for all the auxiliary machinery, lighting, and heating on the locomotive either direct or through the battery which it is charging. When starting the gas turbine power unit the auxiliary generator supplies the necessary power to the main generator which runs as a motor. Finally, the auxiliary gene-

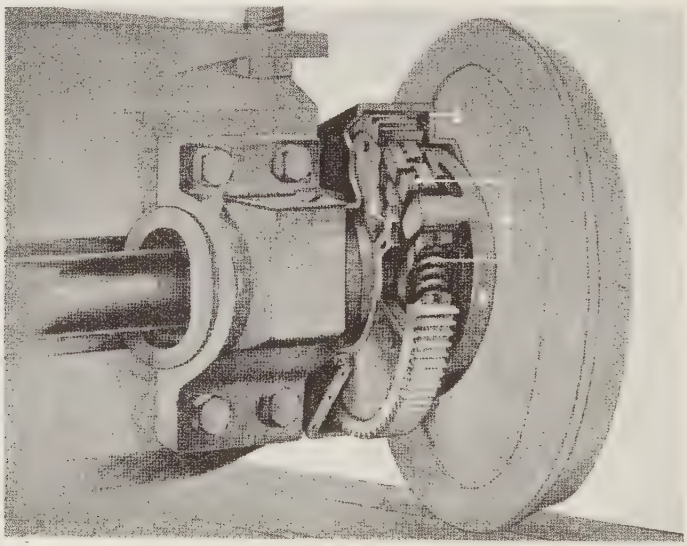
rator can be connected to two of the traction motors (one in each bogie) and thus drive the locomotive as light engine.

The auxiliary generator. — The construction of the auxiliary generator is similar to that of the main generator. The rotor carrying the armature stampings is a hollow steel casting which is flanged rigidly to the flange of the diesel engine. The auxiliary generator has only one bearing which is situated at the commutator end and is of the roller type. The armature lamination assembly is pressed on to ribs on the hollow rotor. The commutator is bolted to the hollow rotor. The brush gear can be rotated. The auxiliary generator is a multipolar machine with counter-compound and starting winding. It has one bearing shield situated at the commutator end. The frame is bolted to the diesel engine so as to form one unit.

The rating of the auxiliary generator is as follows :

Continuous rating : 40 kW at 100 V, 1 150 r.p.m.
Max. working speed : 1 500 r.p.m.

The storage battery. — Due to the use of the auxiliary diesel-driven generator both for starting the gas turbine and supplying the auxiliaries. the storage battery can be kept comparatively small. It serves to start the diesel set and to supply those control and auxiliary circuits which are to be operated without the diesel set running. The Alklum type cadmium-nickel battery consists of 54 cells with a capacity of 200 Ah.

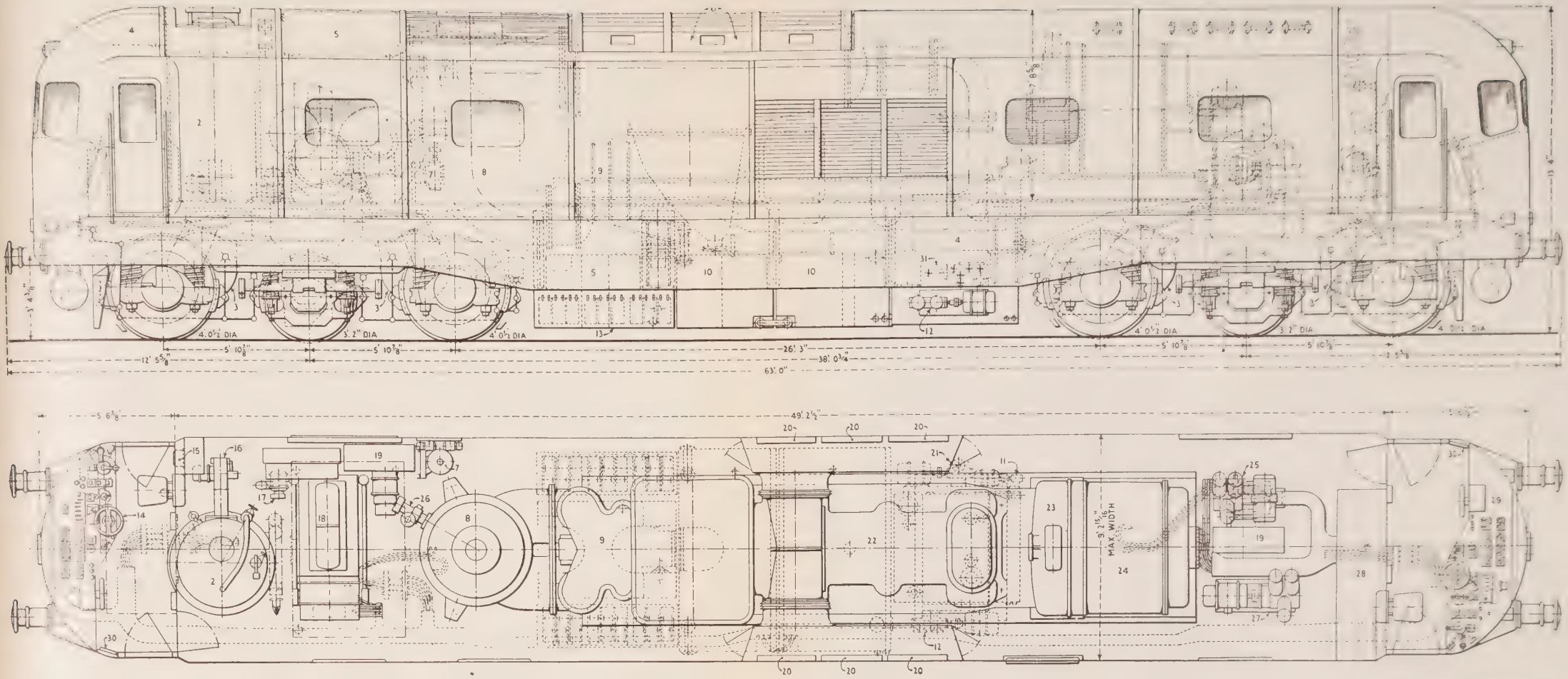


1. Quill stump secured to motor housing. 3. Big gearwheel. 4. Transmission springs. 5. Gearwheel flange lip. 6, Gear case. 7. Driving axle. 8. Carrier disc.

Cross-section view of the axle drive.

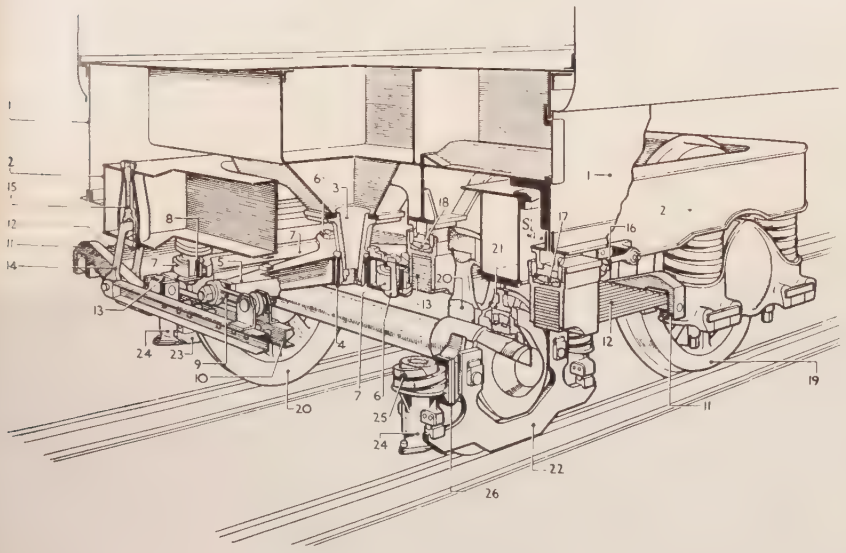
The following auxiliaries are fed from the auxiliary generator or the battery respectively.

Voltage converter set. — The object of this set is to supply at a constant voltage



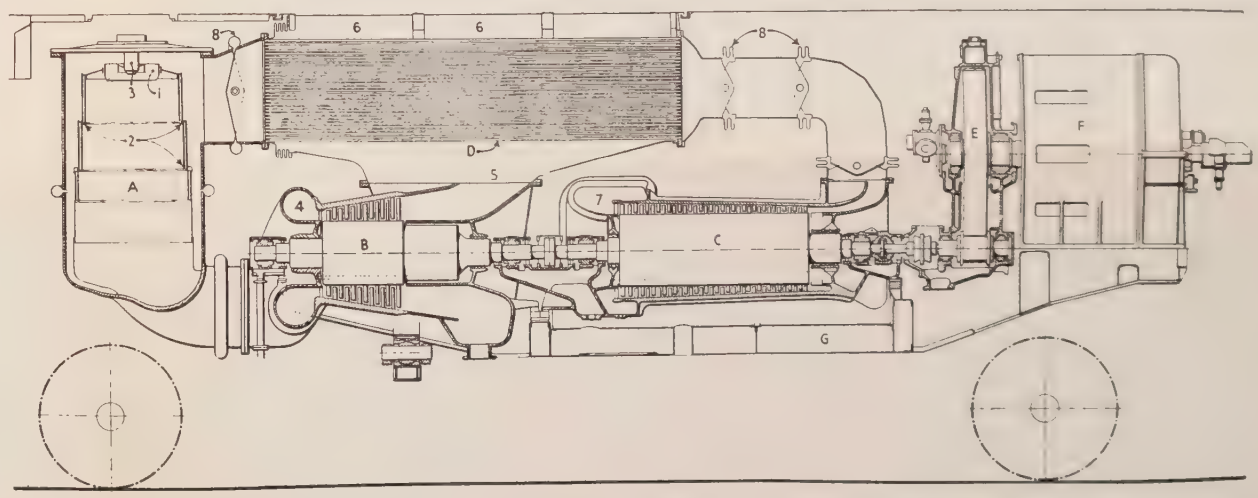
1. Compressed air reservoir for locomotive brakes and apparatus.
2. Train heating boiler.
3. Traction motor.
4. Light fuel-oil tank.
5. Water tank for steam boiler.
6. Heat exchanger.
7. Light fuel-oil pump.
8. Combustion chamber.
9. Gas turbine.
10. Heavy fuel-oil tank.
11. Cooling oil pump.
12. Heavy fuel-oil pump.
13. Storage battery.
14. Main controller handwheel.
15. Cab apparatus of A.T.C.
16. Burner of train heating boiler.
17. Water pump of train heating boiler.
18. Auxiliary diesel-generator set.
19. Blower for traction motors.
20. Air intake and lubricating oil coolers.
21. Control oil pump.
22. Compressor.
23. Reduction gear.
24. Main generator.
25. Belt-driven exhauster-compressor set.
26. Ignition rod.
27. Motor-driven exhauster-compressor set.
28. Electrical apparatus compartment.
29. Driver's desk.
30. Control and repeater panel for marker light.
31. Lubricating and control oil tank.

Sectional elevation and plan of Brown-Boveri gas-turbine locomotive.



1. Underframe of body. 2. Bogie frame. 3. Centre pivot. 4. Silentbloc of centre pivot bearing. 5. Crosshead transmitting the tractive effort and holding the swing bolster transverse beam. 6. Link pin for the drawbar with Silentbloc bearing. 7. Drawbar transmitting the tractive effort. 8. Link pin fixed on the bogie frame with Silentbloc bearing. 9. Connecting link for the swing bolster transverse beam with Silentbloc bearings. 10. Transverse beam for the swing bolster. 11. Cross equalising beam for the body suspension springs. 12. Outer body suspension spring. 13. Inner body suspension spring. 14. Spring hangers. 15. Spring hanger regulating screw. 16. Longitudinal connecting link for the body suspension spring. 17. Outer body side bearing with oil trough. 18. Inner body side bearing with oil trough. 19. Driving wheel. 20. Carrying wheel. 21. Axlebox with self-aligning roller bearing. 22. Outer hanger for carrying axlebox. 23. Inner hanger for carrying axlebox. 24. Axlebox guide with spring seat. 25. Helical spring. 26. Thrust faces. S. Lateral play between bogie and body.

Cross-section of S.L.M. three-axle bogie with lateral play of the middle axle.



A. Combustion chamber. B. Gas turbine. C. Compressor. D. Air pre-heater. E. Gear. F. Generator. G. Bedplate of power unit.

The compressed and pre-heated air enters the combustion chamber partly as combustion air through the squirrel vanes 1. partly as cooling air through the slits 2. The fuel is injected through the injection nozzle 3. The combustion gas and the cooling air mix in the lower part of the combustion chamber on their way to the gas turbine entry at 4. The exhaust gas, which is still hot, passes into the air pre-heater at 5 and is exhausted to atmosphere through slits 6 in the locomotive roof. The air inlet to the compressor is at 7. The air pipe has several expansion joints 8 to deal with the different expansions of the gas turbine set and the air pre-heater.

Section through gas-turbine power unit.

ELEVATION AND PLAN AND DETAIL DRAWINGS OF BROWN-BOVERI GAS-TURBINE LOCOMOTIVE, WESTERN REGION, BRITISH RAILWAYS.

the control and lighting circuits on the locomotive. It consists of a motor and generator built together as one unit. An automatic voltage regulator ensures a constant output voltage.

Control oil pump. — This pump maintains the oil pressure in the hydraulic control systems of the locomotive, as well as lubricating the bearings of the power unit until the speed of the latter is sufficient for the direct-driven lubricating pump to function.

Cooling oil pump. — The cooling oil pump delivers oil to the bearings of the gas turbine after the latter has been shut down so as to remove the heat which they receive from the still hot turbine. The cooling oil set is automatically started on stopping of the gas turbine and stopped by a time switch after sufficient time has elapsed for the gas turbine to cool down.

Pumps for light and heavy fuel oil. — These pumps deliver the fuel to the combustion chamber under sufficient pressure for it to be pulverised at the burner nozzle for combustion. The light oil is used in the turbine during the starting-up period only, until the heavy oil, which is the normal fuel, is sufficiently preheated.

Ignition rod control. — The ignition rod is moved in and out of the combustion chamber by a small electric motor controlled from the driver's desk.

Automatic barring gear. — The object of this gear is to turn the shaft of the gas turbine through 180 deg. at intervals after it has been shut down, so as to avoid a temporary deflection of the shaft whilst it is hot. The barring gear motor is automatically controlled by a time switch.

Blowers for cooling traction motors. — There are two electrically-driven blowers each serving the two motors in one bogie. The blower sets are located in the machine room and are connected by means of ducts and leather bellows to the traction motor cooling air branches.

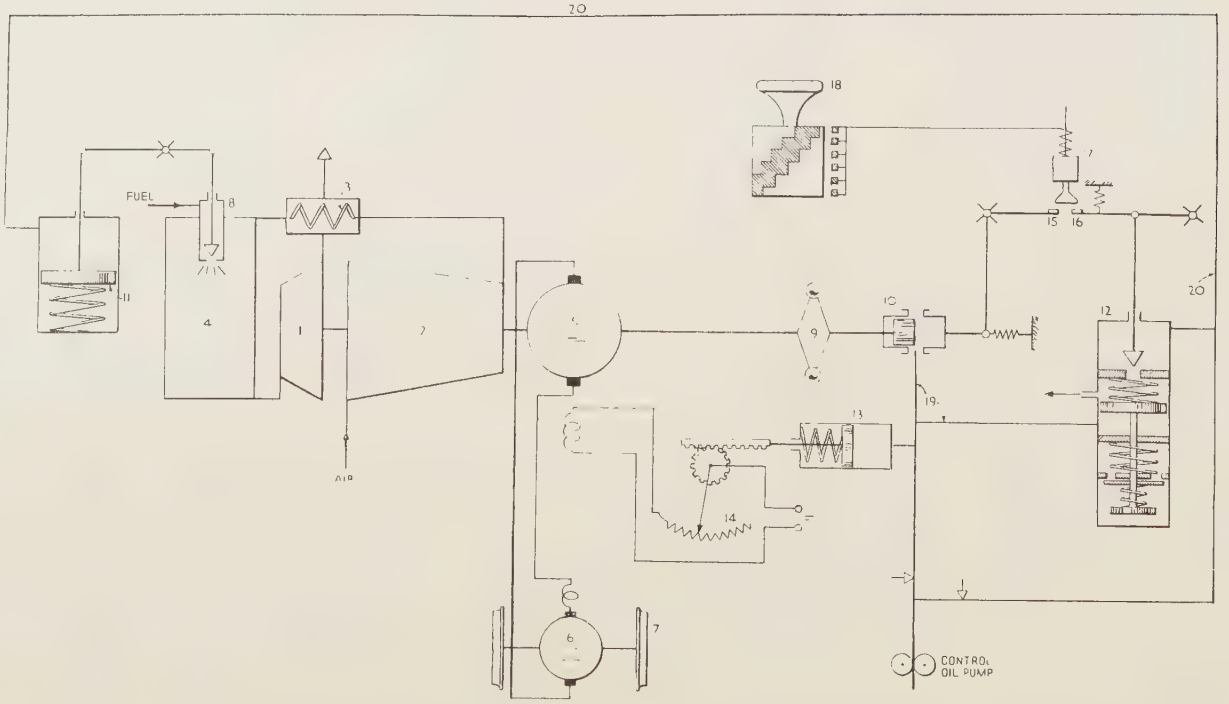
Motor-driven compressor-exhauster set. — Vacuum for the train brake system and compressed air for the locomotive brake system and pneumatic controls is produced by a belt-driven exhauster-compressor set. An electrically-driven set is specially provided to supply compressed air when the gas turbine set is shut down and the locomotive running light on the diesel set, and to boost the production of vacuum for quick release of the vacuum brakes on the train. For this latter purpose it is switched in automatically when the driver places the brake valve in the release position.

Train heating plant. — For the train heating requirements the locomotive carries a Clarkson thimble tube boiler of 1 000 lbs.-h. steam capacity. The boiler is fired with light fuel oil and incorporates two electric motors, for the feed water pump and the burner set respectively.

Operation and control.

All operations for the starting, stopping, and control of the gas turbine power unit, the diesel generator set, and the auxiliaries are remotely carried out from the cabs. All controller handles, push buttons, and supervising instruments are grouped on the driver's desk. They are laid out for one-man operation although, in accordance with British Railways established practice, the locomotice will carry a crew of two.

The first thing the driver will do in boarding the locomotive is to start the auxiliary diesel generator set by pressing a push button. This connects the storage battery to the auxiliary generator which then motors the diesel up to ignition speed. The driver can now switch the auxiliary generator on to the traction motors and in this manner shunt the locomotive at speeds up to about 15 m.p.h. This practice has proved to be very valuable and economical in service because it provides the locomotive with an alter-

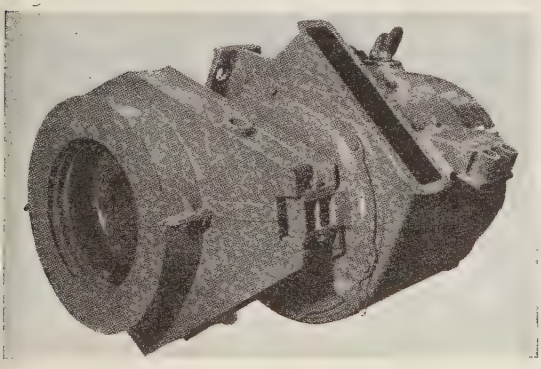


1. Gas turbine.
2. Compressor.
3. Heat exchanger.
4. Combustion chamber.
5. Generator.
6. Traction motor.
7. Driving axle.
8. Burner nozzle.
9. Speed governor.
10. Governor sleeve and regulating valve.
11. Piston.
12. Fuel control pilot valve.
13. Servo field regulator.
14. Resistance of servo field regulator.
15. Speed setter.
16. Fuel supply setter.
17. Electro-pneumatic valves.
18. Controller.
19. Pressure oil piping of speed regulating system.
20. Pressure oil piping of fuel regulating system.

Simplified governing diagram.

native source of power and makes it unnecessary to run the gas-turbine unit for light service requirements.

A few minutes before the train is due to leave, the driver proceeds to start the gas-turbine set. This is done by connecting the auxiliary generator to the main generator, which, running as a motor, accelerates the gas-turbine unit. Meanwhile the fuel pumps have been started, and when the ignition speed is reached the burner nozzle is opened and the light fuel ignited. The thermal unit now accelerates further under its own power, and the diesel generator can be disconnected and switched over to supply the auxiliaries. As stated, starting is normally effected on light fuel oil, but after a few minutes the heavy fuel oil will have been sufficiently preheated, so that the changeover can be effected.



One of the four traction motors.

The driver controls the starting of the train and its subsequent speed through the handwheel of the main controller which acts on the governing system of the locomotive. Each notch of the main controller corresponds to a certain power of the gas turbine unit, this power being determined by turbine speed and fuel quantity. A simplified diagram of the governing system is shown on page 106.

On each notch of the controller 18 an electro-pneumatic valve 17 is actuated which sets the speed of the turbine and the corresponding rate of fuel delivery through the levers 15 and 16, respectively. Lever 16 actuates the pilot valve 12, thus setting the pressure in the control oil system 20, which determines the position of piston 11. This latter sets the opening of the nozzle 8 and thus regulates the rate of delivery of fuel. At the same time lever 15 sets the speed of the gas turbine unit by moving the sleeve of the speed governor 10.

The natural characteristic of the series traction motors is such that these motors do not transmit the same power at all speeds. The governing system must allow for this fact, and it does so by means of the servo-field regulator developed by Brown-Boveri especially for thermo-electric vehicles. In a state of equilibrium, that is, when the locomotive is running at constant speed and tractive effort, the power developed by the power unit corresponds to the output of the generator, the turbine speed remains the same, and the regulation system is not brought into operation.

On the lower notches of the controller, which are used for starting the train, the rate of delivery of fuel is so high that the turbine speed somewhat exceeds the normal value. The speed governor 9 and 10 regulates the pressure of the oil in system 19 to such a low value that the driving piston of the servo field regulator 13 is moved by the pressure of the spring into its right-hand end position so that the resistance 14 is short-circuited and the excitation of the generator brought to its maximum value. As the train gains speed the power demand from the traction motors diminishes. The effect is a tendency of the power unit to raise its speed still further. This is, however, prevented by a reduction in the rate of fuel delivery since, on further increase in the speed of the power unit, falling of the oil pressure in system 19 influences the pilot valve 12.

On the higher notches of the controller,

which correspond to the normal speed range of the locomotive, the traction motors might impose more load on the generator than corresponds to the actual notch position. The servo field regulator now limits the load imposed on the generator by regulating the excitation current. This takes place in the following manner: if, on change of gradient, the traction motors begin to demand more power than that corresponding to the controller position, then the power unit will tend to slow down.

The speed governor 10 now causes the oil pressure in system 19 to rise, so that the piston of the servo field regulator begins to move to the left, thus reducing the excitation current by increasing the resistance 14. The result is that the output of the generator is limited; at the same time the reduction in turbine speeds is corrected and thus a new state of equilibrium reached.

When the piston arrives on its left-hand end position and the current demand from the motors has not yet been fully met, the turbine speed would again start to fall off rapidly, as the servo field regulator can have no further influence. In this case the increase of control oil pressure in system 19 restricts the flow from the pilot valve 12 and thus brings about a limited increase in the rate of fuel delivery. Similarly the reverse takes place when the power demanded by the traction motors diminishes.

The above explains the working of the servo field regulator and its influence on the governing system of the locomotive when the main controller is left in a certain position. If the driver wishes to influence the speed of the locomotive by his own action he need only move the control wheel to a new position. This energises a different electro-pneumatic valve and thus alters the power available.

It might be interesting to follow the action of the governing system in such a case and to see how it shortens the time which the power unit requires to attain the new output value. When « notching up », the speed of the power unit temporarily lags behind the value corresponding to the new setting of the speed governor sleeve 10 because of the inertia of the rotating masses. This will increase the pressure in system 19, thus reducing the excitation current of the generator and, through the action on pilot valve 12, temporarily increasing the rate of fuel delivery above the rate set by the controller. As a result of this simultaneous reduction in electric load and increase in fuel supply the power unit will accelerate very quickly to the new speed. When this is reached the oil pressure in system 19 will fall again and reduce the fuel delivery to the normal rate corresponding to the new controller notch. The piston of the servo field regulator will move and load the generator by increasing the excitation current, which completes the regulation cycle.

When the controller is « notched down » the same cycle occurs with the settings in the opposite direction, the servo field regulator again assisting the power unit in attaining the new output value in the shortest possible time.

On the two last notches of the controller there is no further power increase; instead, the traction motor field is weakened so as to bring about the highest locomotive speeds.

Safety devices.

Incorporated in the control system are a number of safety devices. Service safety is obtained by a number of electrical and mechanical interlocks between the controls to prevent faulty operation. Pilot lamps or instruments on the driver's desk indicate the proper working of all the components, whilst warning lamps light up should excessive temperatures occur in the gas flow.

If, notwithstanding such warning, the driver omits to reduce the load, the fuel pump is automatically shut down, thus

compelling the driver to re-ignite the flame. The fuel pump is also automatically shut down if the speed of the gas turbine set exceeds the normal value by more than 10 per cent., or if the flame in the combustion chamber should go out without the driver noticing it. This latter security measure is controlled by an electronic flame monitoring device and prevents fuel from flowing into the combustion chamber without being burnt. Finally, the locomotive is equipped with the automatic train control apparatus which is standard on the Western Region. The shoe portion of the ATC apparatus is carried by one of the carrying axles of the locomotive.

The cab equipment comprises the driver's desk with the controls and instruments mentioned earlier. The driver's seat is on the right-hand side. In normal train service the driver need only operate the main control hand wheel and, when necessary, the brake handle. He checks the generator load on the special cross pointer instrument developed by Brown-Boveri for thermo-electric locomotives. This instrument indicates simultaneously the generator current and voltage and the locomotive's tractive effort, and, further, shows the driver the appropriate moment for weakening the traction motor fields by field tapping. It does away with the inaccuracies inherent in D.C. wattmeters, particularly for wide variations in voltage and current as they occur in thermo-electric vehicles. The locomotive speed is indicated on an electric tachometer, the generator of which is driven from one of the driving axles.

The cabs are provided with indirect lighting and, in addition, the main instruments are fitted with individual lighting, thus permitting the cab illumination to be switched off during night runs. When in the depot a supply of lighting current on the locomotive is provided from the depot mains supply through two standard plugs, a single-phase transformer, and a change-over switch mounted on the locomotive.

Whilst the train heating is by steam from the Clarkson boiler, the locomotive cabs are equipped with adjustable electric heat supplied from the auxiliary generator. There is also a plug for the connection of a hotplate or tea kettle. The cab windows have electrically heated double panels to prevent freezing.

The electric identification lights at the front and rear of the locomotive are operated from, and repeated on, special panels placed in each of the driver's cabs.

NEW BOOKS AND PUBLICATIONS.

[**625** .113]

SCHRAMM (Gerhard), Dr. Ing. habil. — **Bogengestaltung und Bogenabsteckung.** *(The constitution of curves and their layout on site).* — (One volume (5 3/4 × 8 1/4 in) of 164 pages with figures and tables. — 1949, Bielefeld, Erich Schmidt Verlag, Herforder Strasse, 10. (Price : D. M. 9.80)

The title of the book explains the subject matter. In reality, it is the second part, i. e. the layout on site that is the main subject, but to deal with it is necessary to know what curves are in question. The answer to this question is contained in the first chapter.

A curve is defined by its equation and by the value of its parameters. In this case, we are concerned with circular curves, and transition curves. The latter have to provide the transition between straight sections and the circular curve. Their form depends on the variation in the superelevation and consequently on the radius of curvature. In speaking of these two kinds of curves, the author recalls the rules given in the regulations on the superstructure of the German State Railways.

The methods of making the layout are explained in four other chapters dealing respectively with circular curves without transitions, transition curves of varying constant curvature, transition curves of S curvature, and such curves when used as transitions between circular curves of opposite direction. Another chapter deals with the various problems peculiar to the layout, namely curves of minimum length connecting two straight sections, transition curves absorbing the whole of the circular part, the transitions between two curves of opposite curvature, lining the track, the practical calculation of the geometrical factors defining the arc of a circle.

When it is question of building new railway lines or new routes, the methods which have been reported should be used. But when existing lines have to be corrected, it may be advantageous to make use of the so-called angle diagram method. This is described very fully in a chapter to itself which occupies a large part of the book. It could be used successfully in planning the layout and occupation of new lines and to solve various problems of the technique of curves.

For those of our readers who are interested in this subject, we might mention that an article by the author was published in the February, 1935 *Bulletin*. Another article on the same general ideas appeared in the *Bulletin* for March, 1938. This dealt with the surface survey of lines laid on a curve by means of measuring the versines.

The final chapter describes how a layout should be checked and rectified according to the calculation of the theoretical versines compared with those plotted on the site.

E. M.

[385 (09 (45)]

Le Ferrovie italiane dello State. — (La reconstruzione alla fine del 1949). *(The Italian State Railways. — Their reconstruction at the end of 1949).* One brochure (8 1/4×11 3/4 in) of 52 pages copiously illustrated. — 1949, Rome, Ufficio Stampo del Ministero dei Trasporti.

The Italian State Railways are once again able to offer the public complete services as regards travel and transport throughout the whole length of the country. Two maps head the series of documents intended to show the progress made in four years. A few red lines still show a few lines that have still to be reconstructed, but the absence of which does not impede the general recovery.

The opening to traffic of the great bridges over the Po marks the end of the reconstruction of the system.

Of course temporary constructions had sometimes to be used. As indicated in the introductory note by the General Manager, M. G. di Raimondo, Engineer, the work to be undertaken during the second stage will be to replace these temporary structures by permanent ones, and to improve the technical equipment, the modernisation of which has already begun.

Information by pictures is used very successfully. This gives us a collection of photographs chosen to illustrate the most remarkable achievements in the various sections of the railway : permanent way, bridges, service buildings, staff housing, tunnels, telecommunications, safety and signalling equipment, production and use of electric power, electrification of the lines, laboratories, ferry-boats, steam and electric locomotives, rail motor coaches, electro-trains, wagons, stores, specialist staff, provident societies and staff funds.

A brief note explains the guiding principles which govern activity in each division. A diagram compares the position in 1939, 1945 and 1949. It shows that little remains to be done to catch up with the 1939 level.

At times the figures for 1949 even surpass those of 1939. This is the case with accommodation for the staff which exceeds that available pre-war by nearly 4000.

All these details are summed up in a statistical table : reconstruction in figures, supported by another showing the part played by American aid in the reconstruction of the Italian State Railways.

A few diagrams show the improved services and traffic recovery from 1945. The number of passenger-kilometres has increased to nearly double that of 1938-39. In the case of goods traffic, the figures have practically returned to the same level. This is one of the effects of the reduction in national production and also of the results of road competition.

In the part dealing with the reform of the tariffs, it will be seen in particular that the line of the kilometric rates has been inflected a little more after 1 000 km in the case of passenger traffic and after 600 km in the case of goods traffic. The basic rates compared with the pre-war ones remain in the proportion of 1 to 25 in the case of passengers and 1 to 26 in the case of goods, whereas the average cost of living has increased in the proportion of 1 to 50.

Finally the economic health of the undertaking has been encouraged by the technical improvement of the installations and the adaptation of the number of employees to the operating necessities. A few diagrams of the variations of the characteristic indices show the results obtained in this connection.

E. M.

[621 .332]

Calculo, planos de construcción y ensayos de una linea catenaria para electrificación de ferrocarriles. *(Calculation, constructional plans and tests for an overhead line for electric railways).* — Publication of the Laboratory for railway research of the Roads, Harbours and Canals Engineering School. — Publication No. 4. — Madrid 1948. — One volume (8 1/4×11 in.) of 142 pages copiously illustrated.

An example of a carefully studied overhead line is that the Madrid-Alcazar line. Use was made of certain terms of comparison from previous electrifications, such as the Madrid-Avila-Segovia, Irun-Alsasua and Barcelona-Manresa lines.

In erecting such a line, the engineer has to solve many problems and the solutions adopted can have a great influence on the installation and running costs. The researches and calculations reported in this publication bear witness to the need for carrying as far as possible the analysis of the mechanical and electric phenomena, and as a result, the exact determination of the stresses to which the constituant parts are subjected in order to arrive at the best utilisation of the materials.

The principal characteristics are : feed at 3 000 V, metal posts 75 m apart, line consisting of a carrying cable 152 mm² in section and a grooved contact wire 130 mm² in section, the droppers supporting the wire being spaced at intervals of 12.50 m. There are compensation gear with balance weights on the contact wire. On the other hand the carrying cable is secured to the brackets of the posts and consequently follows any variation in length due to changes in the temperature and load.

A general note explains the considerations which led to the choice and justify the arrangements adopted, based on the calculations developed in the following notes.

The choice of a single contact wire of 130 mm² section gives rise to a discussion on the pressure due to the wind, compared with a line with two wires. Wind pressure was the subject of trials carried out in the Laboratory of the National Institute of Aeronautical Technique the results of which are given and commented upon in an appendix. Careful estimation of the maximum current to be allowed for and the voltage at the points of collection show the advantages of this proposal compared with an existing line.

The study of the deformations of the catenary necessitated fairly long numerical calculations if the equation for the catenary is to be referred to in each case, or even an approximate equation. For the sake of simplification the authors constructed a nomogramme which they have used to a considerable extent, This was done by tracing the parabolic curve representing the existing relation between the excess length of the arc over the span on the one hand and on the other the ratio between the tractive effort and the total weight of the wire. The value of the versine can be read from a graduated scale along the curve. This nomogramme enable the effects of an overload, or of an alteration in the temperature to be dealt with conveniently, and an erection table plotted showing the versines and tractive efforts corresponding to various temperatures. It is also made use of in the investigation into the plastic behaviour of the cables. Many additional plates are included showing the actual nomogrammes used to solve the various problems arising.

Amongst the question, which were the subject of detailed calculations, mention may be made of the following : the distance between droppers (on which the different levels and slopes of the contact wire depend), the distance between the posts (on which the stresses in the carrying cable and the possibility of the line getting out of centre depend), the length of the droppers (which affect the level of the contact

wire when it is displaced longitudinally owing to variations in the temperature). A detailed analysis of the displacement of the contact wire due to the action of the balance weights, which is countered by the oblique position taken by the droppers, led to the distance between balance weights being fixed at twice 825 m.

As the carrying cable is not compensated, its centre point rises and falls according to circumstances, and the distance between the two extremes compared with the distance between posts gives the « coefficient of quality » of the line. This can also be determined by using the nomogramme.

The layout of the line and the spacing of the posts on curves, and the passing of the current from the feed cable to the carrying cable are other questions considered in detail.

In the construction of the posts welding has been largely used. Two types have been used. The first is in the form of a rectangular tube obtained by welding 4 mm folded sheets; the second is a lattice type formed of two sections with the flanges set together and joined by welded flats. The work includes a thorough investigation into the forces to which the posts can be subjected together with a determination of the stresses and deformations resulting therefrom.

Compared with other installations the saving in weight in the posts is considerable. However before the designs were passed, trials were carried out on actual posts. A description is given of the installation erected for this purpose, with a detailed account of the experiences and measurements made.

Although these studies were made with a given electrification scheme in view, they can also serve as a basis for the equipment of other lines. The importance of this will be appreciated when it is remembered that the decree of January 1946 authorised an electrification programme covering 5 263 km of lines.

The economies made affected not only the posts but all the component parts of the overhead line. They are due to the choice of a voltage of 3 000, by adopting the maximum falls in voltage permitted by the approved standards, adapting the organisation of the trains to the new method of traction, and a rational design of the transmission line. In addition, the tensions allowed in the constituant parts were carefully chosen and the determination of the real stresses very carefully done to assure the maximum guarantee of safety.

Specialists will greatly profit by reading this publication. Its interest lies first of all in the arrangements allowed for the proposed electrification, and finally in the various considerations, methods and calculations which decided its adoption.

E. M.

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CHAUDRON (G.). — **Recent French investigations in the field of light alloys.** (3 400 words & fig.)

Modern Transport. (London.)

1950 **625** .4 (42)
Modern Transport, March 4, p. 8; March 11, p. 7.
VALENTINE (A.B.B.). — **Planning new Tube Railways for London.** (3 800 words & fig.)

1950 **625** .14 (42)
Modern Transport, March 11, p. 14.
Permanent way developments. (1 500 words & fig.)

1950 **656** .212 (44)
Modern Transport, March 18, p. 13.
GUIBERT (R.). — **French Railway terminal services.** (2 250 words.)

1950 **621** .33 (42)
Modern Transport, March 25, p. 3.
HURCOMB (C.). — **Electric traction in Great Britain.** (1 800 words.)

1950 **621** .431.72 (42)
Modern Transport, March 25, p. 5.
HARPER (F.A.). — **Diesel-electric power on British Railways.** (1 800 words & fig.)

1950 **625** .4 (42)
Modern Transport, March 25, p. 7.
GRAFF-BAKER (W.S.). — **Multiple-unit trains.** (1 600 words & fig.)

Proceedings, The Institution of Electrical Engineers. (London.)

1949 **621** .33 (42)
Proceedings, The Institution of Electrical Engineers, December, p. 835.
Discussion on « Electric traction on the Southern Railway ». (3 000 words.)

Railway Age. (New York.)

1949 **625** .251
Railway Age, December 31, p. 40.
EKSERGIAN (C.L.). — **Wheel slip and passenger-train braking.** (4 300 words.)

1950 **625** .28 (73
Railway Age, January 7, p. 178.
WEIHOFEN (G.J.). — **Developments in motive power.** (1 700 words & fig.)

1950 **621** .33 (42)
Railway Age, January 14, p. 20.
RIGG (J.). — **Britain continues electrification program.** (800 words & fig.)

Railway Engineering and Maintenance. (Chicago.)

1949 **625** .172 (73)
Railway Engineering and Maintenance, December, p. 1177.
GARDNER (W.E.). — **Lubrication solves frozen-joint problem.** (1 600 words & fig.)

1949 **625** .174 (73)
Railway Engineering and Maintenance, December, p. 1184.
FLEMING (J.J.). — **Big machines defeat big snow troubles.** (1 200 words & fig.)

Railway Gazette. (London.)

1949 **621** .335 (68)
Railway Gazette, No. 23, December 2, p. 647; No. 27, December 30, p. 765.
South African Railways « 3E » Class electric locomotives. (*To be continued.*) (5 000 words & fig.)

1949 **621** .33 (49)
Railway Gazette, No. 24, December 9, p. 675.
Electrification and new construction in Luxembourg. (600 words & map.)

1949 **656** .254 (42)
Railway Gazette, No. 24, December 9, p. 676.
Divisional control room organisation L. M. R. (1 400 words & fig.)

1949 **621** .132.1 (54)
Railway Gazette, No. 24, December 9, p. 679.
Vulcan 2-8-2 « YD » class locomotives. (300 words & fig.)

1949 **625** .173 (73)
Railway Gazette, No. 24, December 9, p. 680.
A Diesel-electric track sweeper. (700 words & fig.)

1949 **385** (08 (42)
Railway Gazette, No. 24, December 9, p. 685.
British Transport Commission Annual Report. (1 500 words.)

1949 **621** .132.6 (42)
Railway Gazette, No. 25, December 16, p. 703.
Bagnall 0-6-0 « 400 » class tank engines. (300 words & fig.)

1949 **625** .14 (42)
Railway Gazette, No. 25, December 16, p. 704.
Track stabilisation at Waddesdon, Eastern Region. (600 words & fig.)

1949 **656** .212.7 (44)
Railway Gazette, No. 25, December 16, p. 705.
Goods shed at Pantin, France. (400 words & fig.)

1949 **621** .135.1 (42)
Railway Gazette, No. 25, December 16, p. 709.
Standardisation of British Railways locomotive cabs and controls. (600 words & fig.)

1949 **625** .232 (42) & **625** .4 (42)
ailway Gazette, No. 26, December 23, p. 733.
Rolling stock for London Transport. (1 800 words fig.)

1949 **625** .617 (44)
ailway Gazette, No. 26, December 23, p. 736.
CAZENAVE (C.R.). — **Railway wagon transporters France.** (1 000 words & fig.)

1949 **656** .235 (42)
ailway Gazette, No. 26, December 23, p. 741.
Charges scheme for merchandise traffic. (5 000 words.)

1949 **625** .13 (485)
ailway Gazette, No. 27, December 30, p. 763.
Main-line bridge replacement in Sweden. (600 words fig.)

1949 **621** .335 (494)
ailway Gazette, No. 27, December 30, p. 764.
Swiss « Re 4/4 » locomotives in service. (500 words fig.)

1950 **621** .134.1
ailway Gazette, No. 1, January 6, p. 11.
MacARD (G.W.). — **Determining working loads and resses.** (3 000 words, tables & fig.)

1950 **621** .132.4 (54)
ailway Gazette, No. 1, January 6, p. 16.
ARGAWAL (P.R.). — **Pacific locomotives for Jodhpur ailway, India.** (800 words & fig.)

Diesel Railway Traction. (London.)

1949 **625** .285 (8)
Diesel Railway Traction, December, p. 221.
REED (B.). — **Railcars for South America.** (2 400 ords & fig.)

1949 **621** .431.72 (73)
Diesel Railway Traction, December, p. 225.
Extended range of American locomotives. (1 200 words & fig.)

1949 **621** .431
Diesel Railway Traction, December, p. 227.
MacARD (G.W.). — **Fuel-tank gauges and meters or rail vehicles.** (1 500 words & fig.)

1949 **621** .431
Diesel Railway Traction, December, p. 233.
Diesel motive power working. (1 400 words & fig.)

1949 **621** .431
Diesel Railway Traction, December, p. 236.
Factors affecting the choice of Diesel power. (800 words & fig.)

Railway Mechanical Engineer. (New York.)

1948 **625** .232 (73)
Railway Mechanical Engineer, December, p. 71.
New cars for the Twentieth Century Limited. (2 000 words & fig.)

1948 **625** .234 (73)
Railway Mechanical Engineer, December, p. 76.
GILLICK (H.L.). — **Heating long trains.** (600 words.)

1948 **621** .431.72 (73)
Railway Mechanical Engineer, December, p. 78.
Diesel mechanical maintenance. (5 500 words.)

1948 **621** .431.72 (73)
Railway Mechanical Engineer, December, p. 100.
FAUERBACH (W.F.). — **Brushes for Diesel-electrics.** (1 200 words & diagr.)

1948 **656** .254 (73)
Railway Mechanical Engineer, December, p. 103.
Erie's radiotelephone system. (1 600 words & fig.)

1948 **621** .431.72 (73)
Railway Mechanical Engineer, December, p. 107.
HENSHAW (M.D.) & CATLIN (F.H.). — **Black lighting for cab dials.** (1 000 words & fig.).

1949 **625** .24 (73)
Railway Mechanical Engineer, January, p. 1.
KIEFER (P.W.), MIERS (A.M.) & HAYS (L.D.). — **Development of pacemaker box cars.** (5 000 words, tables & fig.)

1949 **621** .431.72 (73) & **665** .882 (73)
Railway Mechanical Engineer, January, p. 6.
REX (R.L.). — **Diesel locomotive maintenance welding.** (3 000 words & fig.)

1949 **621** .438 (73)
Railway Mechanical Engineer, January, p. 11.
STEINS (C.K.). — **The coal-burning gas-turbine locomotive.** (1 200 words.)

1949 **625** .234 (72)
Railway Mechanical Engineer, January, p. 13.
Radiant heat in Mexican car. (1 000 words & fig.)

1949 **621** .138.3 (73)
Railway Mechanical Engineer, January, p. 15.
HITCH (C.B.). — **Maintenance of steam power.** (1 200 words.)

In Danish. (= 439.81.)

Ingeniøren. (Copenhagen.)

1950 **625** .142 .4 (489) = 439.81
Ingeniøren, No. 14, p 291.
PETERSEN (E.). — **Reinforced concrete sleepers** on the Danish State Railways. (1 700 words & fig.)

1950 **625** .7 (73 = 439.81 & **691** (73) = 439.81
Ingeniøren, No. 15, p. 338.
DANØ (K.). — Building of **roads in reinforced concrete** in U. S. A. (2 200 words & fig.)

In Spanish.

Boletin de la Asociación permanente del Congreso Panamericano de Ferrocarriles. (Buenos Aires.)

1950 **625** .144.2
Boletin de la Asoc. perman. del Congreso Panameric. de Ferrocarriles, enero-febrero, p. 64.
LOPEZ GUEVARA (H.). — Estudio de la **sobreelevación** en vias de ferrocarril. (3 000 palabras & fig.)

1950 **621** .431.72
Boletin de la Asoc. perman. del Congreso Panameric. de Ferrocarriles, marzo-abril, p. 35.
KLIP FARRINGTON, Jr. (S.). — El **progreso de la tracción Diesel.** (4 000 palabras.)

1950 **621** .33 (44)
Boletin de la Asoc. perman. del Congreso Panameric. de Ferrocarriles, marzo-abril, p. 45.
ARMAND. — Nuevas **perspectivas de la electrificación** en Francia. (2 000 palabras & fig.)

Revista de Obras publicas. (Madrid.)

1950 **625** .13
Revista de Obras publicas, marzo, p. 138.
JUAN-ARACIL (J.). — **Ventilación en tuneles.** (5 000 palabras & fig.)

In Italian.

Alluminio. (Milano.)

1950 **624** .2 & **669** .71
Alluminio, nº 2, p. 122.
RUFF (W.). — Studio fotoelasticimetrico sull' **alleggerimento di una trave.** (5 000 parole, tavole & fig.)

Ingegneria ferroviaria. (Roma.)

1950 **385** .114 (45)
Ingegneria ferroviaria, marzo, p. 155.
MATERNINI (M.). — La ricerca dei **costi effecttivi delle unitá di traffico** sulla rete ferroviaria statale italiana. (8 000 parole, fig. & tavole.)

1950 **625** .113
Ingegneria ferroviaria, aprile, p. 231.
POLSONI (G.). — Considerazioni sulle **curve di raccordo ferroviarie.** (2 500 parole & fig.)

1950 **621** .133.7 (45
Ingegneria ferroviaria, aprile, p. 261.
MICHELUCCI (A.). — Il **trattamento dell' acqua delle caldaie** delle locomotive nella rete delle F. S. (2 000 parole & fig.)

1950 **624** .6
Ingegneria ferroviaria, maggio, p. 297.
KRALL (G.). — **Armature metalliche centine per ponti in cemento armato** e nuovi metodi d'impiego informati alla viscosità dei calcestruzzi. (4 000 parole & fig.)

1950 **656** .25
Ingegneria ferroviaria, maggio, p. 307.
RIGHI (R.). — Il calcolo dei **circuiti di binario** muniti di relè ad un elemento. Esame del problema ristretto. (6 000 parole & fig.)

1950 **625** .24
Ingegneria ferroviaria, maggio, p. 321.
CIRILLO (M.). — L'**unificazione del materiale da carico nel servizio internazionale.** (3 000 parole & fig.)

1950 **656** .225 & **656** .261
Ingegneria ferroviaria, giugno, p. 377.
BÄSELER (W.). — Le **casse mobili come mezzo per il risanamento economico delle ferrovie** e per la collaborazione fra strada e rotaia. (3 000 parole & fig.)

1950 **656** .1 (45)
Ingegneria ferroviaria, giugno, p. 397.
VEZZANI (F.). — **Entità e costo degli autotrasporti** al 1° aprile 1950. (1 500 parole & tavole.)

In Netherlands.

Spoor- en Tramwegen. (Utrecht.)

1949 **621** .33 (481)
Spoor- en Tramwegen, Nr. 26, 29 December, p. 425.
BAYENS (F.). — **Electrische tractie** in Noorwegen. (1 700 woorden & fig.)

1950 **621** .338 (492)
Spoor- en Tramwegen, Nr. 1, 12 Januari, p. 3.
DOUWES DEKKER (C.E.). — De **nieuwe electrische vierwagenstellen** der N. S. (2 000 woorden & fig.)

1950 **625** .141
Spoor- en Tramwegen, Nr. 2, 26 Januari, p. 19.
NOYON (S.). — Langzame schuivingen in de ondergrond als oorzaak van **ballastzakken.** (4 000 woorden & fig.)

1950 **656** .222.5 (492)
Spoor- en Tramwegen, Nr. 4, 23 Februari, p. 53.
VAN LITH (F.J.). — De **ontwikkeling van het personenvervoer** in Nederland na de tweede wereldoorlog. (1 600 woorden & fig.)

1950 **656** .212 (42)
oor- en Tramwegen, Nr. 4, 23 Februari, p. 60.
De goederenloods te Birmingham. (2 700 woord. & fig.)

1950 **656** .212 .5
oor- en Tramwegen, Nr. 5, 9 Maart, p. 76; Nr. 6, 23 Maart, p. 90; Nr. 7, 6 April, p. 105.
De methode tot het **gelijktijdig samenstellen** van inen. (9 000 woorden & fig.)

1950 **656** .222.5 (492)
oor- en Tramwegen, Nr. 6, 23 Maart, p. 85.
PUTMAN (J.J.). — De **treindienstregeling** te Amsterm Centraal Station. (1 500 woorden & fig.)

1950 **621** .33
oor- en Tramwegen, Nr. 6, 23 Maart, p. 98.
DOUWES DEKKER (C.E.). — **Electrische tractie t eenphasige wisselstroom 50 perioden** en vergelijkende schouwingen met andere systemen. (2 000 woorden.)

In Swedish. (= 439.71.)

Järnvägs-Teknik. (Stockholm.)

1950 **625** .162 (485) : **656** .254 (485) : 439.71
nvägs-Teknik, No. 2, p. 42.
HÅRD (T.). — Report of 1948 relating **to level ssings.** (2 800 words.)

1950 **621** .33 (485) = 439.71
nvägs-Teknik, No. 3, p. 66.
SPÅNBERG (T.). — First trials of **electric traction** Sweden. (1 800 words & fig.)

1950 **625** .212 (44) = 439.71
nvägs-Teknik, No. 3, p. 80.
PINAT (P.). — **Railway carriages with pneumatic es.** (750 words & fig.)

Nordisk Järnbanetidskrift. (Stockholm.)

1949 **625** .112 (481) = 439.82
rdisk Järnbanetidskrift, No. 11, p. 315.
LORANGE (R.). — **Reconstruction of small gauge lway lines** in Norway. (Paper read at the Meeting of Nordiska Järnvägsmannasällskapet (Section B), in lo, in October 1949.) (3 600 words & fig.)

1949 **625** .141 (485) = 439.71
rdisk Järnbanetidskrift, No. 11, p. 331.
OLSSON (T.). — **Ballasting works and transport of last.** (Paper read at the Meeting of the Nordiska nvägsmannasällskapet (Section B), in Oslo, in Octo- 1949.) (3 800 words.)

1949 **656** .216 (489) = 439.81
rdisk Järnbanetidskrift, No. 12, p. 345.
Cartage of small parcels traffic for small stations and their district for collection and delivery. (Paper read at the Meeting of the Nordiska Järnvägsmannasällskapet (Section D), at Gothemburg, in September 1949.)
HUMLE (L.). — Danish report. (3 200 words.)
LENNES (J.). — Finnish report. (350 words.)
PRYDZ (E.). — Norwegian report. (1 100 words.)
SVENSSON (T.). — Swedish report. (1 500 words.)

1949 **656** (471) = 439.71
Nordisk Järnbanetidskrift, No. 12, p. 360.
Means of concentration of export traffic in view of a close co-operation between railways, ports, ship-owners and exporters. (Paper read at the Meeting of the Nordiska Järnvägsmannasällskapet (Section D), at Gothemburg, in September 1949.)
BLASSAR (A.). — Swedish report. (3 500 words.)
LOKEN (K.). — Norwegian report. (800 words.)
JONSON (E.). — Swedish report. (1 200 words.)
ERIKSON (G.). — Swedish report. (1 500 words.)

1950 **624** .2 : **625** .1 (471) = 439.71
Nordisk Järnbanetidskrift, No. 1, p. 5.
Temporary **railway bridges.** (Lecture given at the Meeting of the Nordiska Järnvägsmannasällskapet (Section B), held in Oslo, in October 1949.)
PEITSARA (A.). — Finnish report. (1 600 words & fig.)
BROEN CHRISTENSEN. — Danish report. (1 000 words & fig.)
KILLINGMO (A.). — Norwegian report. (1 200 words.)
CARLSTEDT (A.). — Swedish report. (800 words.)

1950 **656** .257 = 439.81
Nordisk Järnbanetidskrift, No. 1, p. 23.
WESSEL HANSEL (W.). — **Safety installations with relays.** (1 300 words.)

1950 **625** .286 (483) = 439.71
Nordisk Järnbanetidskrift, No. 1, p. 27.
BLIMSTRAND (Y.). — **Electric railcar** of the Möj railways (Mellersta Östergötlands Järnvägar). (300 words & fig.)

Spårväg och Buss. (Stockholm.)

1950 **656** .25 : **625** .42 (485) = 439.71
Spårväg och Buss, No. 5, p. 74.
BOBERG (I.). — **Signalling system on the underground railway in Stockholm.** (2 900 words & fig.)

Teknisk Tidskrift. (Stockholm.)

1950 **621** .335 : **625** .42 (485) = 439.71
Teknisk Tidskrift, No. 18, p. 415.
OFVERHOLM (H.). — **Rolling stock of the underground railway in Stockholm.** (4 600 words & fig.)

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